Hydraulic, Steam & Hand Power

Lifting & Pressing Machinery

Frederick Colyer, C. E

HYDRAULIC, STEAM, AND HAND POWER

LIFTING AND PRESSING MACHINERY.

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AND

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BY

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'WORKING AND MANAGEMENT OF BOILERS AND ENGINES';
'PUMPS AND PUMPING'; 'MODERN STEAM ENGINES';
'CONSTRUCTION OF GAS WORKS'; ENGINEERING OF PUBLIC INSTITUTIONS';
'WATER SUPPLY AND DRAINAGE;'
'MODERN SANITARY APPLIANCES FOR RESIDENCES.'

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PREFACE TO THE FIRST EDITION.

The author, having heard a desire expressed by many for a practical treatise upon Hydraulic, Steam, and Hand-Power Lifting and Pressing Machinery, has been induced to undertake the task. The work is addressed to engineers whose practice has not been in this branch of engineering; also to architects and users of such machinery, to give them an insight into the same, and to afford some help, either in design or as a guide to the adoption of machinery suitable to the special requirements of the particular case.

The machinery and work described, except in the cases specially mentioned, are from the author's own experience. Assuming that practical men are chiefly addressed, he has not gone into any rudimentary descriptions, but has only mentioned such details as may be useful for the purpose. Very little discussion is entered into relative to the value of certain machines, for the same reason; but the few results given from practice may prove more useful. He trusts that the work may be acceptable to those who are seeking information in this branch of practice.

The work has been written in a concise form, as it was thought it would be more acceptable to those addressed to have practical facts and data expressed in as few words as possible.

The author has to express his thanks to Messrs. Clark and Standfield, Mr. R. H. Tweddell, Mr. J. B. Ellington, Messrs. Thornewell and Warham, and Mr. H. Adams, for their courtesy in affording

information on the specialities designed and made by them. Also to the Council of the Institution of Civil Engineers, for their courtesy in allowing the author to use Drawings Nos. 4, 5, 6, 7, 9, 10, 13, 16, and 17 from the *Transactions* of the Institution, vol. 50.

FREDERICK COLYER, M. INST. C.E., M. INST. M.E.

18, GREAT GEORGE STREET,
WESTMINSTER, S.W.
July, 1881.

PREFACE TO THE SECOND EDITION.

The first edition of this work having been well received, a new and revised edition has been issued. The original work has been extended and much extra matter added, together with many new drawings. The original design of the book has been kept in view, in adopting a concise manner in the descriptions of work given. In each section new examples have been given of modern types of machinery, the whole matter has been brought up to date, and most leading types of work noticed.

The Author expresses his thanks to Messrs. Sir W. G. Armstrong, Mitchell and Co., Limited; Messrs. Easton and Anderson, Limited; Messrs. Simpson and Co., Limited; Messrs. Stodhert and Pitt, Limited; Messrs. Grafton and Co., and Mr. E. B. Ellington, M.I.C.E., who have kindly rendered assistance in enabling him to describe some special work designed by them.

FREDERICK COLYER, M. Inst. C.E., M. Inst. M.E.

18, Great George Street,
Westminster, S.W.

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HYDRAULIC LIFTING MACHINERY.

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HYDRAULIC HIGH-PRESSURE LIFTING MACHINERY.

Erratum.

Page 7, line 7, *should read:*—In the former case the Load in lbs. $+ \frac{1}{10}$ for friction $\div$ pressure in lbs. per square inch will give the area of the cylinder; in the latter case, the Load in lbs. $\times$ number of movable pulleys $+ \frac{1}{4}$ for friction, $\div$ P in lbs. per square inch will give area of the cylinder.

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The useful effect obtained from direct-acting hydraulic apparatus is about 93 per cent.; and when short-stroke cylinders, combined with movable pulleys, are used, it varies from 60 per cent. (at 10 to 1) to 75 per cent. (at 4 to 1);—this is assuming the machinery to be of

PART I.

HYDRAULIC LIFTING MACHINERY.

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HYDRAULIC HIGH-PRESSURE LIFTING MACHINERY.

The first practical use of water for the transmission of force was made by Bramah, in the hydraulic press of which he was the inventor. It was patented in 1796; he also intended to use the same system as a motive power for cranes and other machines. For transmitting power to great distances, water is the most suitable, and, in the end, most economical; it possesses many advantages over other plans, of which the author treats in another place. The hydraulic system, as applied to cranes and other lifting apparatus, was first brought into extensive use by Sir W. G. Armstrong, now Lord Armstrong, to whom the author wishes to bear full testimony as the pioneer of most of the work done since in this branch of engineering. From the success which attended his first efforts in this way, in 1846, may be traced the researches of others in the same line, and the execution of most important and successful works. The author does not intend here to go into the question as to the relative cost of lifting by hydraulic power, as compared with other plans; he will add a few remarks as to this towards the end of this section of the book (see p. 56).

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the best kind. In most of the large docks and railway depôts in London and elsewhere, hydraulic quay cranes are usually made fixtures; portable cranes are, however, in use in many places. They possess many advantages, which will be duly noticed hereafter. The circumstances of the work to be done, and arrangement of the place, must decide which is the most suitable plan. There is no difficulty in connecting the water pressure from the main pipes to the cranes. The junction at the desired points can be easily and quickly made. Machinery for this class of work will be described hereafter in detail. The engines for pumping the water under pressure, and the boilers to supply steam for same, are the first consideration; these are usually placed at a convenient spot—where possible, about midway between the work to be done; this, however, is not of great moment, because, in the case of docks and railway companies, to satisfy the fire insurance companies, and reduce the amount of the premiums on the policies, the engine and boiler houses are often placed outside the dock or depôt, the mains being carried a considerable distance from the engines and pumps, in some cases upwards of a mile or more. Special arrangements in this case are necessary as to the accumulators and valves, which are described in another place.

The application of hydraulic machinery is a large and most important subject; the author has hereafter fully treated most of the apparatus in general use. If more detail is mentioned than seems necessary to practical men, the excuse is, so little appears to be known by many engineers, architects, and users of this class of machinery, that it is hoped the details given in this book may be some guide to them in laying out such plant, and will help to show where it can be usefully employed.

Methods of Obtaining Water Pressure for Working Cranes and Lifts.—There are several systems by which the requisite water pressure in the pipes for working hydraulic apparatus is obtained; some of the machinery is worked at a high pressure, and some at a low pressure. All pressures up to about 70 lbs. square inch may be considered low pressures. The means that have been employed are detailed below.

1. *Head of Water from a Tank.*—The water is pumped up by

engine power to a tank placed on a tower of brickwork, or on the top of a building, in some cases 200 feet high; mains are carried from it to distribute the pressure to the various machines as required. The most notable instance of this, and also on the largest scale, is the one still existing at the Great Grimsby Docks; the tower in this case carries a wrought-iron tank, holding 33,000 gallons of water, at about 200 feet from the ground line; the size of the top of the tower is 26 feet by 26 feet, and 28 feet by 28 feet at the base. The walls are 4 feet thick at the base, and 3 feet thick at the tank level; the supply pipe is cast iron, 13 inches diameter. The water is pumped up by a pair of engines situated at the ground level. Owing to the great cost of such apparatus, especially as regards the foundations for the walls for *high-pressure* work, this plan is seldom used. It has, however, one advantage over other systems: the tank forms a large reservoir of power, and allows the cranes to be used for a certain period independent of the engines, and consequent attendance of the men in charge of the same. As there is always a steady pressure in the pipes, they are less liable to leak at the joints. It must, however, be borne in mind that a head of 200 feet, equal to 87 lbs. per square inch, is not an economical pressure to work at for *high-pressure machinery.*

2. *Air Vessels.*—Water is pumped into wrought-iron air vessels under pressures of 200 to 250 lbs. per square inch; but the difficulty in keeping them properly charged with air and retaining the pressure is so great that this plan has been generally superseded by the accumulator system next named and fully described in the following chapter. It must be borne in mind that these remarks only apply to *high-pressure* work, as air vessels are still advantageously used for pressures up to 150 lbs. on the square inch; and, in places where accumulators are too costly and would take up too much space, the air-vessel system is to be recommended. A small air-pump is employed to keep up a steady supply of air in the receiver, and thus maintains the required working pressure in the pipes. The air vessel should be well made and double riveted at the joints, and of ample size for the work; the pumping power should also be large, to be equal to any sudden demand upon the apparatus. The author prefers to make the air vessels small in diameter and high, in

preference to a larger diameter and less height, as he believes the air is not so quickly absorbed in this case by the water, and in this way less trouble is caused in keeping up the pressure in the pipes and machinery worked.

3. *Accumulators.*—To obtain pressure in hydraulic mains of from 400 to 750 lbs. per square inch and above, accumulators are more generally employed than any other system. They consist of a loaded ram working in a cylinder, which is placed near the pumping engine in the line of the pressure pipes. As the water is pumped by the engine it raises the loaded ram, and so gives the requisite pressure in the mains. The contents of the cylinder of the accumulator is adjusted to suit the number of cranes, lifts, and other apparatus to be worked, so as to ensure that sufficient water under pressure is available for any sudden demand. The engines are controlled in their speed by automatic apparatus connected with the ram of the accumulator, by which means, as the ram rises and falls, the engines run at a corresponding speed. When no pressure is being taken from the mains, the engines run very slowly; directly the ram falls, the steam throttle-valve is opened in proportion, and the engines run at the necessary speed. It will thus be seen that the work done by the engines is proportionate to the demand for pressure at the various cranes, lifts, &c., worked by it. Cast-iron mains, 3 inches to 4 inches in diameter, are led from the accumulator to the various apparatus to be worked. At the commencement of working the engines fill the mains, and as the pumping is continued the ram of the accumulator rises, and so gives the necessary required pressure in the mains. Safety valves are provided at various points, to relieve the pipes from undue pressure. Air-valves are also attached, to keep the pipes free from air. The engines and accumulators may be placed, as before named, some distance from where the cranes, &c., have to be worked; it is only a question of the length of pipes to convey the pressure. When the distance is more than 1 to 2 miles, it is advisable, whenever possible, to place additional accumulators at different points, to ensure that an equable pressure is maintained. There are several great advantages in employing the hydraulic high-pressure system, as in places it can be used where boilers would not be permitted, as well as in cases where, from other causes, it

would be impossible to find room for pumping machinery at the place where the cranes are used.

The pressure in the mains supplied by hydraulic accumulators for cranes, hoists, and lifts is from 700 to 750 lbs. per square inch; the latter pressure has been found by experience the most economical for general working. In some instances much higher pressures have been used, even up to 1500 lbs. per square inch; but it is open to question if this is the most economical method of working. Difficulties seldom take place from the freezing of the water in the mains; in cases where the pipes and machinery are more than usually exposed, it has been found convenient to use a mixture of glycerine with the water, in the proportion of about 1 to 6; this prevents any damage from frost. In the case of slight frosts, a proportion of from 1 to 1¼ gallons of glycerine to about 275 or 300 gallons of water is sufficient. Experience appears to show that the higher the pressure the less liability there is to freeze. At the first introduction of hydraulic machinery by Sir W. G. Armstrong and Co., much difficulty arose from the leaking and breaking of the joints, as well as the bursting of the pipes; the firm above-named, however, adopted the two-lug joint so well known, and also made many subsequent improvements in the jointing material. With some slight modifications by other firms, it is the form in almost universal use, and answers its purpose admirably. Too much praise cannot be accorded to the original inventor. The author can with gratitude say, the general form of apparatus and system of working has been the model on which he has designed most of this kind of work in his own practice. He does not think the great service rendered to the hydraulic system by Sir W. G. Armstrong (now Lord Armstrong) has been so fully appreciated as it should be.

The London Hydraulic Power Company have laid their mains in the public streets of London and elsewhere since the first edition of this book was written. The mains are always under a pressure of 750 lbs. per square inch, a supply from which can be obtained at a very moderate rate. It is most useful and convenient, and has been the means of considerably extending the use of hydraulic lifts and cranes, both for public establishments, such as hotels, public offices, warehouses public and private, railway stations, and wharves. Here-

tofore the high-pressure system could not be used, on account of the expense in the pumping machinery and the cost of the intermittent working of the same. The author believes Hull was the first town to adopt this system. The work was designed and carried out by Professor Robinson, M. Inst. C.E. The original idea is, however, due to Lord Armstrong, who first proposed the system, but did not carry it out as a public installation. The author had the same scheme in his mind about twenty-five years since, but found, upon mentioning the idea, he had been forestalled by the gentleman last named.

CHAPTER II.

HIGH-PRESSURE HYDRAULIC MACHINERY.

The machinery for supplying water under heavy pressure to work cranes, hoists, and other lifting and hauling machinery consists of pumping-engines and boilers with hydraulic accumulators and service of cast-iron pipes to the various apparatus.

For Wharf-Cranes.—The machinery consists of horizontal or vertical cylinders of a stroke either equal to the height of the lift or multiplied by chains running over movable pulleys. In the former case the pressure in lbs. per square inch + $\frac{1}{10}$ for friction will give the diameter of the ram; in the latter case, P in lbs. × number of movable pulleys + $\frac{1}{4}$ for friction will give area of the ram. For ordinary loads the stroke of the cylinder to the height raised is usually about 6 or 8 to 1. The more direct the power is applied, or rather the less number of movable pulleys that are employed, the less will be the friction, and the consequent increased efficiency of the machine. The most economical pressure in the water-mains for working high-pressure lifting apparatus has been found to be 750 lbs. per square inch; at this pressure water is usually supplied by the Hydraulic Power Companies. For ordinary average loads up to 30 cwt. one lifting cylinder is usually employed, but where the load varies two cylinders are provided; this plan effects much saving in the water used. The swinging of the crane is accomplished by two separate cylinders worked by an independent valve-box, by means of lever and rod. The rams of these cylinders, through the medium of chains, act direct on the lower part of the crane post, the stroke being proportioned to give the required amount of travel. In most cases the cylinder and ram gear, together with the rest of the machinery, is placed under the ground-level, unless the cranes are for the purpose of unloading ships direct,

when they are placed on a platform of sufficient height to permit the jibs to clear the sides of the vessels; in this instance the machinery is situated between the under side of the platform and the ground level.

For Warehouse Cranes.—The machinery for operating is usually attached to the inner side of the wall of the warehouse, and at the highest floor, near the jibs; the cylinders and rams are either single or double, as in the case of wharf cranes, and of a stroke multiplied by movable pulleys in proportion to the height to be raised. The swinging of the load is usually done by two separate cylinders, acting through chains direct on the lower part of the jibs; two separate pressure valve boxes, with working levers and rods, are also provided. In some instances it has been found quicker and more economical to adopt automatic means for swinging the cranes, which will be described in detail in its proper place. For platform cranes used on the ground floor of a warehouse or depôt for unloading wagons and carts, &c., the lifting cylinders are usually placed between two side cheeks of the crane-post, the stroke of the cylinders being made equal to the maximum height to be raised; these cranes are direct acting, and much complication is avoided in the chain gear, as well as much saving in the friction of working. There are several modifications of the arrangements of the machinery for working these kind of cranes, which are described in detail hereafter.

For Hoists and Lifts.—There are two systems of working:—

1. By direct acting cylinder and ram, the ascending table, or cage, being fixed direct to the top of the ram, which is made the same stroke as the height to be raised; the cage is guided by two bars, running the whole height. The pressure is regulated by a valve-box, having levers, rods and ropes in connection, the latter pass through the cage, and by this means the starting and stopping is accomplished. The rams are made hollow, and when the lift is more than 10 to 12 feet are made in about 9 feet lengths of steel, screwed together; the cylinders are cast-iron, and are sunk in the ground to a depth equal to the height to be raised. Proper apparatus is provided to prevent the lifts overrunning, automatic gear being attached to stop it at the highest and lowest points before any shock can be communicated to the cage. Counterbalance

weights are sometimes provided to take part of the weight of the ram and cage; in this case the weights are grooved at the sides, and are run in angle-iron guide-bars which are sunk in a recess in either side of the well-hole. The cages are entirely enclosed, the roof being made of boiler plate-iron; this is to prevent anything that might accidentally fall doing injury to the persons or goods inside the cage during raising or lowering.

2. By short cylinders and rams, with movable pulleys, as before described; the seshould *not*, however, be used when *passengers are to be raised*, as the lifting is done by a chain from which the cage is suspended at the centre. The same remarks as at p. 1 apply to the use of this system as regards the friction, &c. The only reason for adopting this plan for high lifts is because it is less costly than the direct-acting ram system, no boring in the ground is required, and less expensive machinery can be used. Safety-gear, which will be hereafter described, is provided in this case and is attached at the top of the cage. In case the rope or chain breaks, the cage is at once held by wedges, and prevented from falling and doing damage. There are several forms of this class of machinery suitable for different purposes, all of which will be fully described under their own section.

The following apparatus can also be worked by high-pressure hydraulic power:—

Capstans for moving trucks, &c.
Machinery for working dock gates.
" " sluices.
Swinging bridges.
Docking vessels, &c.
Turntables for railways.
Working movable platforms.

An Installation of machinery for high-pressure hydraulic machinery consists of the following, viz.:—

Hydraulic Pumping-Engines.—Specially constructed either on the condensing, compound, or three-cylinder systems; the pressure-pumps, which are double acting, in each case are worked direct from the main piston-rods.

Boilers.—To supply steam, the Cornish or Lancashire type, or the Babcock and Wilcox patent water tube system may be employed. Ample steam room is provided, to be equal to any sudden demand for pressure.

Accumulators.—One or more of these is provided, the capacity being equal to the quantity of water under pressure that is required to work about one-third of the cranes or hoists. The engines have, however, sufficient pumping power to keep up the supply if all the machines are used at one time.

Pipes.—To convey the pressure to the different machines; these are usually sunk in the ground, except in the case of factories or warehouses where they are carried on the walls; in all cases they must be protected from the weather.

Machinery.—Consisting of long and short stroke rams and cylinders, details of which are hereafter given; these apparatus are provided at each crane, hoist, or other apparatus, some being of special construction to suit particular cases.

Engines for Pumping.

There are several types of engines employed for pumping water for hydraulic machinery. Each particular case will have to be treated according to the magnitude of the installation and the special circumstances of the case. The engines may be of the following types:—High-pressure or non-condensing, or compound high- and low-pressure engines, and either in the horizontal or vertical forms. A pair of engines in each case are coupled, having one crank-shaft and fly-wheel common to both. Each of these forms will be described suitable for average installations.

Horizontal High-pressure Engines.—For an average small plant, engines of this type are generally employed. The pumps are either placed directly in front of the steam cylinders or at their back end; in both cases they are worked direct from the piston-rods; the former system is adopted when the floor space is limited. In this case the piston-rods are attached to the cross-heads on one side and direct to the plungers of the pump on the other. The connecting-rods are made in the form of long forks spanning the pump-barrels, and terminating at the crank pins in marine ends lined with gun-metal. The pumps thus form the guides to the piston-rods, hence much room is saved; the only disadvantage in connection with this

system as compared with the other is, that the pump-valves are not so readily got at. There are, however, many instances in which the compactness of the engines would more than out-balance this. The steam cylinders are the ordinary type and are fitted with D slides, they are steam-jacketed, felted and lagged with wooden staves on their exterior.

The pumps are double-acting and provided with rams and pistons; the valves are of india-rubber with intermediate discs of steel—only small lift is given to them. The fly-wheel is heavy, turned on the rim and well-balanced. The speed of the engines varies from 30 to 300 feet per minute.

No. 2 Type.—In this case the engines are provided with guides and sliding-blocks of the usual kind; each of the pumps are placed at the back of the cylinders and are worked direct off the piston-rods; the valve-boxes are fixed outside the pumps and are easily accessible for adjustment and repairs. The respective merits of this and the system previously described have been already entered into.

Example of the work performed by high-pressure non-condensing engines. A pair coupled with cylinders 12 inches in diameter and 24 inches stroke, worked with steam at 90 lbs. per square inch, the pumps being 4½ inches in diameter, and double-acting, will deliver about 130 gallons of water per minute at 750 lbs per square inch. The number of hydraulic apparatus supplied by engines of this size is about 30—1½ ton cranes—say 15 hydraulic engines for working capstans, sluices and bridges, and one or two 3-ton cranes. The accumulator for engines of this size is 18 inches in diameter and 20 to 21 feet stroke; in cases where a larger reserve of power is required the stroke must be increased.

Compound Hydraulic Pumping Engine by Messrs. Sir W. G. Armstrong, Mitchell & Co., Limited. This type of engine is built in the horizontal form, and is suitable for pumping water for hydraulic apparatus for large installations, at working pressures from 750 to 1,500 lbs. per square inch.

The engines are coupled, and have one crank shaft and fly-wheel common to the two; the high-pressure cylinders and piston-rods are coupled by connecting-rods to the cranks. At the tail end of each

cylinder the piston-rods are prolonged and are attached to the pistons of the low-pressure cylinders, which are placed immediately behind—the piston-rod of each of these latter cylinders are attached direct to the plungers of the pumps. The construction of these does not vary from those described for the high-pressure engines, except the arrangement of the valve-boxes, which are placed in the position shown, and thus permit of ready adjustment and repairs when necessary. All the fixed parts of the engines are bolted to massive bed-plates held to the foundation by long holding bolts and plates. The cylinders, jackets and steam-pipes are all protected by non-conducting composition, and are lagged with mahogany. Ample means are provided for oiling all parts and for draining the condensed water from the cylinders. The fly-wheel is made heavy and is carefully balanced. The pressure of steam is usually about 100 lbs. per square inch in the high-pressure cylinders. In the example given in the Drawing No. 2 the high-pressure cylinder is 19$\frac{3}{4}$ inches in diameter, and the low-pressure 37 inches in diameter, both having a stroke of 3 feet 2 inches. The maximum speed is 45 revolutions per minute. The combined indicated HP. with full load pumping under a pressure of 750 lbs. per square inch is 450. The quantity of water delivered by the two pumps is 620 gallons per minute. The condensers are placed in a horizontal position directly under the low-pressure cylinder. The air pumps are placed vertically at the crank end and are worked by a separate connecting-rod; guides and cross-heads are provided as shown. It will be noticed the whole forms a very compact arrangement. The speed of the engines is governed by the special gear connected with the accumulator described at p. 3.

Much economy is effected by the use of compound engines for pumping-work of this kind. In comparing, however, the consumption of fuel with ordinary water-work engines, it must be remembered the work of the former is intermittent and the load irregular, while in the latter case the work is constant and regular.

The Worthington Pumping Engine (Drawing No. 3).—These engines, made by Messrs. James Simpson & Co., Limited, London, are also used for pumping water into hydraulic mains for working cranes and other machinery under pressures of 750 to 1,500 lbs. per square inch. The engines have been installed at the Bristol and

Avonmouth Docks as well as at the Grimsby Docks, a description of which is hereafter given. The general principle of construction, as far as the steam cylinders and valve gear are concerned, does not materially differ from the engines described in full detail in the author's book—Part I. 'Pumps and Pumping Machinery' (Spon)—except as regards the arrangement and detail of the pumps. In these hydraulic engines there are two pumps to each engine, one of each of which is placed directly in front of each steam cylinder, each pump having an additional one at the back of it. There are eight sets of valve boxes to each pump, each being provided with eight separate valves. The plungers are cast hollow and are $7\frac{1}{8}$ inches in diameter by 3 feet 6 inches stroke. The pumps facing the steam cylinders are attached direct to the cross-heads, to which the piston-rods are also connected; at these cross-heads side rods are attached and carried to the cross-heads fixed to the hindmost pumps. The high-pressure cylinder is $19\frac{1}{2}$ inches in diameter, and the low-pressure 32 inches in diameter, and the same stroke as the pumps. The pressure of steam used is 60 lbs. per square inch; the maximum number of strokes is 25, at which speed 600 gallons of water per minute are delivered into the mains and accumulator under a pressure of 700 lbs. per square inch. The engines in this installation supply power for all the cranes, hoists and capstans, as well as power to turn or swing the bridges, and to open all the dock gates. All the work done, as before stated, by hydraulic pumping engines for the purposes named is of an intermittent character, and for this reason—such a high ratio of economy cannot be attained as in the case of the engines when employed for steady pumping for the water supply of towns.

Engines of this type are capable of pumping water for hydraulic cranes, &c., under pressure up to 1,500 lbs. per square inch; as before noted, 750 lbs. is the most economical pressure to adopt for hydraulic machinery.

A pumping engine of this type has also been erected at the Cossipore Foundry, India; it pumps water into an accumulator at a pressure of 1·5 ton per square inch.

VERTICAL TRIPLE COMPOUND PUMPING ENGINES (Drawing No. 4).

These engines were designed by Mr. E. B. Ellington, M.I.C.E., for supplying water under pressure for working hydraulic accumulators. They consist of three inverted cylinders, each working hydraulic pumps direct from the piston rod; the three cylinders work on to one crank shaft. The cranks are set at an angle of 120°; there being no dead point the engines are in perfect balance. The pumps give a perfectly steady and even flow of water, and work very smoothly at a speed of 250 feet per minute. In cases where the floor-space is limited they are a suitable and economical engine; the Author can with confidence recommend their use. These engines are a modification of the three-cylinder compound engines, full details of which, with a drawing, will be found in Part II. of the Author's book on Pumping.[1] The triple engines working with 150 lbs. pressure of steam have an economy considerably in excess of the earlier engines working compound only with one high-pressure and two low-pressure cylinders. The triple engines work with about 14 lbs. of water per indicated high-pressure per hour, and are the most economical engines for this class of work of any yet constructed. The mechanical efficiency is as high as 84 per cent.

No governor is required for any of the pumping engines described; the automatic gear connected to the rising and falling head of the accumulator ram controls the speed of the engines according to the work to be done. It acts in this way: At the top of the ram or loaded cage, a system of rods and levers is connected to the throttle valve of the engine; as the ram rises to the full stroke, the steam, by means of the gear, is nearly shut off at the throttle valve, and as the ram falls the valve is gradually opened, giving a supply of steam as required. The apparatus is self-acting and is most effective in working.

The Foundations for all these Engines must be of a solid character; a good bottom must be obtained on which a bed of concrete should be

[1] 'Pumps and Pumping.' By F. Colyer, M. Inst. C.E. E. & F. N. Spon, London.

laid varying in thickness with the power of the engine and the depth of the excavation. The brickwork should be built in Portland cement, and on this should rest a stone, either Yorkshire or Portland—the former is preferable, and as a rule cheaper. The kind of stone used will of course depend on the locality where the machinery is placed. The engine must be well bolted to the foundation by bolts at least 3 feet 6 inches to 5 feet long. A perfectly rigid and solid fixing of hydraulic engines is a necessity, and upon this will very much depend the perfect working of the engines and their subsequent wear.

Boilers.

These may be of the Cornish or Lancashire type, or the Babcock and Wilcox's patent water tube system; they should be placed in a house near to the engines, so that the same man who attends the engines can also superintend the stokers in the boiler-house. The boilers should be of ample capacity to meet any unusual demand upon the engines.

All the above-named boilers are set in brickwork and have the usual fittings. The pressure of steam varies, ranging from 60 lbs. per square inch to 150 lbs., and above in the case of triple expansion engines.

The Babcock and Wilcox Boilers for the latter pressure are specially suitable, as they are perfectly safe under pressures of 160 lbs. to 200 lbs. per square inch; they also possess this advantage, they can be put into confined places and passed through narrow passages where it would be a very costly thing to put in one of the Cornish or Lancashire type. They are also portable for sending abroad and up the country in remote districts, and in places where the moving and delivery of heavy weights is a grave consideration.

Multitubular Boilers upon the locomotive plan may also be used in many places with advantage, especially when it is difficult to build foundations; they require no setting, and can be easily removed if desired. They are also of much advantage where pressures above 80 lbs. per square inch are wanted; they are economical in working,

but require more attention as the steam is generated very rapidly, and the steam space is usually rather small. Where this system is adopted, the fire-box type, such as made by Messrs. Marshall & Sons, Limited, of Gainsborough, is the most suitable. These boilers are made of steel plates, and are very strongly stayed; great attention is paid to their careful design as well as perfect manufacture. *Feed* pumps should be provided as well as injectors; the feed water should be passed through a heater, the exhaust steam from the engines being passed either through the tubes or casing of same.

Water for Pumping.—In the case of docks, most of the water after use is returned to the dock; but in smaller places it is used over again, so there need be but little waste; this is specially necessary when glycerine is used in the water in frosty weather, it would otherwise be too expensive a process to adopt in most instances. The water in this case is returned by separate mains into a large receiving tank equal in capacity to the total quantity of water required for all the cranes and lifts, &c. It is very important to keep the water clean and free from grit and dirt; all tanks should be covered, and cleaned out at stated periods.

The tanks should be placed under cover and be well protected from the weather; the sides may be felted and covered with wood lagging; the suction pipe must be placed within a small chamber which should form a filter, it being most essential to obtain the water free from grease, dirt, and dust. When the water is contaminated in this way it does much injury to the interior of the cylinders and also to the rams and leather packings.

Accumulators.

The water pressure for working cranes, hoists, &c., is usually given by the above apparatus, which consists of a loaded ram working in a cylinder, similar to a hydraulic press. The top of the ram carries a cage made of cast iron, loaded with iron, stone, or other material, to give a dead load direct on the same; this counterbalance cage, with the ram, rises and falls between two iron guides fixed to strong timbers. Water is pumped into the cylinder until the required

pressure is obtained; this varies from 400 to 750 lbs. per square inch, the latter being considered the most suitable and economical for working cranes, hoists, and other apparatus. The cylinders and rams for the above pressure are made of thick metal, in order to stand heavy shocks. In the accumulators first made, the casing containing the load rose and fell *above* the cylinder, but in those more modern they are made with an annular or double casing, forming a hole in the centre, and allowing them to work *over* the cylinder, as shown in No. 1 Drawing. The base plates for the cylinder must have powerful ribs, and be well bedded on a sound foundation; the base plate should be cast separate from the cylinder, to ensure sound castings in both cases, and also to facilitate fixing. The cage, or round case for the counter-balance, is made of wrought iron $\frac{3}{8}$ inch thick, with stay rods fixed to a cast-iron crosshead fitted to the head of the ram to take the weight of same. Self-acting gear is fixed to the top of the cage to regulate, by means of the throttle-valve, the speed of the engines to suit the work. Safety valves are fitted to the pipes, to give relief in case of sudden stoppage. *Self-acting air valves* are also provided, to avoid shocks.

The action of the "Accumulator" is thus:—At the commencement of the pumping all the pipes are filled, the branch pipe leading to the accumulator cylinder being on the main pipe, the loaded ram is raised; if no crane, &c., is wanted at the time, the engines are stopped by the automatic gear when the ram is full up. All the pipes are now charged to the full working pressure; directly, however, pressure is required from the pipes, by using any crane or other apparatus, the ram falls and the valves of the engines are again opened by the self-acting gear, and the pumping is recommenced, so keeping up the required amount of pressure. The area of the ram and its stroke depends upon the class of work; as a rule, for ordinary installations, not more than the contents of three to six crane cylinders are allowed. The pumps and engine power should be sufficient for the largest demand that can be made in any emergency. The distance from the accumulator to the cranes is not a matter of much moment; but where the pipes have many bends and follow a circuitous route, extra accumulators are usually provided at various points. This specially applies when the work is done at a railway depôt, dock, or wharf, and where the cranes are a long dsitance apart.

The useful effect of the "accumulator" is about 80 to 85 per cent. The wear and tear, provided clean water is used, is very small, and the consequent repairs are almost *nil.*

The pressure pipes used are cast-iron, 2, 3, 4, and sometimes 6 inches diameter, $\frac{7}{8}$ to $1\frac{1}{4}$ inch thick, with faced joints, and provided with two lugs at the flanges, they are held together by $1\frac{1}{4}$-inch diameter bolts and nuts; safety valves are fitted at various points on the pipes, and means taken to protect them from frost.

Hydraulic Cranes.

Cranes for docks, wharves, and railway depôts, &c., are usually constructed as shown in Drawing No. 5. Taking a 2-ton crane as a type, the posts are made either of cast or wrought iron, fixed to a cast-iron base plate. The jib works round on turned parts at the head and base of the post; it is formed of wrought-iron plates, either like a riveted girder, or two slabs or plates, strutted apart by cast-iron distance pieces riveted through each side cheek or plate, or with wrought-iron bracings also riveted to the side cheeks; this keeps the jibs from raking. The top wheel is 18 inches in diameter by 3 inches wide, with a plain groove in which the chain works; in order to reduce the friction, the groove should be turned; the pin on which the top wheel runs should be $1\frac{3}{4}$ to 2 inches in diameter. At the top and bottom of the post, cast-iron frames with bored bosses are provided; these are connected by two wrought-iron side plates all firmly riveted together. The top frame carries the chain-wheel at top of the post. At the base of the post a grooved chain-wheel is fixed; this is for the purpose of swinging the crane. The lifting chain passes through the centre of the post.

Working Cylinders (see Drawing No. 6).—The cranes are worked by cylinders fixed horizontally under the quay or jetty, with rams working through stuffing boxes or leather packing; the diameter of the rams and their stroke depend upon the weight and height to be lifted. To the head of the ram is fixed a carriage with movable pulleys. The lifting chain is attached to the base of the cylinder, it then passes over the movable and fixed pulleys, giving the necessary travel to the chain for the height to be lifted. To swing the crane

two separate cylinders are used, having chains passing from the ram-heads to a grooved wheel keyed upon the jib-post, near the bottom. The cranes are worked by two valve boxes and two sets of valves—one to control the raising and lowering, the other the swinging. Air valves and safety valves are provided to each crane, to take any sudden shock and so prevent fracture. At some wharves the cylinders cannot be sunk below the ground line; in this case the jib is fixed upon a platform, and the ram cylinders between the under side of same and the top of the wharf. This has the additional advantage that the jib is kept clear of the sides of the vessel when the level of the water rises. For small weights and low lifts, the cylinders are usually fixed in the hollow part of the crane post; the post in this case is formed of two flat plates which are riveted to cross head plates, working at the top and bottom parts on turned pins. The same arrangements are made as before as to the stroke of the rams in the cylinders compared to the height to be lifted.

Where craft have to be unloaded from a V-shaped jetty some distance from the front of the warehouse, a special jib is fixed on framing, and at a sufficient height to keep the floor of the jetty clear to land the goods; the jibs in these cases are from 25 to 30 feet radius, and sometimes more. Cranes of this kind give the advantage of landing both at the wharf level, and also into one or more floors of the warehouse when it is situated within about 25 feet of the edge of the wharf.

Power of Cranes.—Wharf cranes are usually made to carry 35 to 40 cwt., and for exceptional weights one or more cranes are provided, capable of lifting from 3 to 5 tons, fitted with two or more lifting cylinders; when not wanted for the maximum heavy weights one lifting cylinder only is used, and so loss of power is avoided; or where the business is large, entirely separate cranes are employed for the heavy weights. For cranes to lift above 10 tons, it is advisable to apply auxiliary hand power to enable these occasional weights to be raised, the strength of all the various parts being made sufficient to take the maximum load; a movable block is used in such cases. Taking the average work at a wharf or depôt such heavy weights have seldom to be dealt with: it would not pay in such cases to have such heavy and powerful machinery for occasional use. To avoid this the above plan is recommended.

Direct-Acting 160-Ton Hydraulic Crane.

These fine cranes, shown in Drawing No. 7, were designed, made, and erected, by Sir W. G. Armstrong and Co., to lift and load heavy guns, boilers, and other weights. They are used in docks and shipyards where very heavy weights have to be lifted. The lifting power consists of a cylinder suspended from the crane head, with ram and piston working in the same. The lift is made direct from the ram, and not by means of chains or gear; the swinging gear does not much differ from the usual plan. The jib and all its parts are wrought iron, very powerful and carefully proportioned. Such a crane is of necessity only used for heavy and special lifts; the action is slow, to avoid any undue strain. The height lifted is about 40 feet. The Author believes this type of crane is the only safe method of dealing with such heavy weights. They are of necessity very costly, but as they have to deal with goods of great value, a larger outlay for such apparatus is true economy in the end.

They are manipulated with the greatest ease, and are of much value in large docks, as before stated, where heavy weights often have to be dealt with. The foundations must be carefully made, and must rest on a sound bottom; in places where the ground is soft or marshy timber piles should be driven, and a platform of timber should be laid at least 6 inches thick; on this concrete should be laid, and on this the masonry or brickwork is placed built in Portland cement. The base-plate, which is a massive casting, is secured to the foundation by long holding-bolts and girder-plates.

Movable Hydraulic Cranes (Drawing No. 8).

For dock and wharf work cranes are often made portable, and are run on rails fixed at the ground level to any desired spot. Hydrants are placed at various points in the pressure mains, with convenient means of attachment at the base of the crane; a sliding or telescope pipe is used to admit of some adjustment. The crane is usually made with the working cylinder fixed inside the post—it is more convenient for light weights to dispense with swinging gear by

hydraulic power. The valve motion is the same as in the other cranes. The jib is constructed in much the same way as for the cranes named at p. 18; a counter-balance is attached at the back part. It will be noticed the bottom part of the jib at its attachment to the side frames of the post is kept up some distance above the ground line; this permits it to clear the sides of the vessels at high-water level.

This class of crane possesses many advantages for dock or wharf work, especially in the latter case, the wharf usually being by the side of a tidal river. At the fall of the tide the vessel grounds, and when discharged, or all the goods taken out of one hold, the crane can be moved on to the next hold, or to another ship or craft. Some difficulty was experienced at the first use of these movable cranes, on account of the pipe joints leaking; subsequent improvements have now got over this difficulty. A leading dock manager, and a great authority on lifting, lately stated, "he would always use hydraulic cranes in a dock; but in any new dock he would prefer to have them movable."

It must be borne in mind, to make hydraulic cranes pay they should be at work as many hours as possible; the above plan allows of this, it also lessens the number of cranes required at a wharf or dock; and thus keeps the wharf or quay clear, and allows of extra space for the stowage of goods, and the easier passage for men.

Ellington's Patent Movable Hydraulic Winch.

This is shown on Drawing No. 9; it consists of a Brotherhood's three-cylinder engine, on the shaft of which is keyed a double drum with brake-wheel, supported on a substantial iron framing fitted with wheels and axles. The front wheels are made so as to turn under the frame for convenience in moving about. The weight of the apparatus is more than sufficient to balance the load to be lifted, and only requires to be kept steady by chocks placed under the wheels.

The engine is controlled by a balanced valve, which is used for starting, stopping, or reversing. In most cases the machine is used with an up and down rope or chain, passed over snatch-blocks. At each lift the engine is reversed, and the only overhauling weight

required is that sufficient to balance the chain. Where working with a single chain, by placing the handle of the controlling valve in a different position, the water already in the engine cylinder is allowed to circulate and acts as a water brake, the overhauling weight being sufficient to turn the movable parts.

A series of jointed pipes allows a convenient amount of movement of the apparatus without disconnection with the pressure main, the exhaust water being led back to the return main through a length of hose. The brake is added as an additional precaution to be worked by a handle, and is powerful enough to hold the engine with the pressure on, while it enables the apparatus being used without the engine as a lowering jigger. The machine takes the place of fixed cranes in discharging vessels, and can, if desired, be placed on the deck. It is also used by builders and contractors in towns where a sufficient pressure of water exists in the public mains. A very high speed of working is obtained, and the height of lift is practically unlimited.

Post Cranes for Railway Work.

The details of the jibs are much the same as before described, but the working cylinders with multiplying chains are fixed inside the hollow posts, which are usually formed of two wrought-iron slabs. Drawing No. 10 shows this crane in detail. For light weights no swinging gear is attached. The arrangements for the supply of pressure and discharge of waste water are shown in the enlarged detail. The working lever is placed near the foot of the crane-post. In cases where the lift does not exceed 5 to 6 feet, direct-acting rams may be employed; they are very useful cranes, rapid in working, and are easily controlled. Special arrangements are made, as shown in Drawing No. 11, where the ram cylinder forms part of the post. The crane in this case is swung by the usual separate cylinders; these cranes are very handy where the weight and height to be lifted do not materially vary. In many cases, especially when the weights are light, no swinging-gear is attached, this operation being easily performed by hand power. The valve gear for both these cranes is of the usual type, and is worked by levers at the base

of the crane. There are several modifications of this type of crane to suit special circumstances; they are not, however, of sufficient consequence to make it necessary to describe them in detail.

Warehouse Cranes.

The jibs consist of two wrought-iron slabs with cast-iron distance pieces between; rivets pass through from cheek to cheek. The jib-head carries a grooved wheel about 16 to 18 inches diameter; the chain passes from the cylinders through the foot and up the hollow post of the jib, to this pulley. The hook is made with a safety spring, and near this is fixed a cast-iron ball sufficiently heavy to run out the chain. The jib is carried on a cast-iron plate, well bolted to the walls, provided with top and bottom bearings for the turned parts of the jib to work in. Pipes should be carried from inside the building to the various pins and bearings, for the purpose of oiling them.

Working Cylinders.—These are the same as described for the wharf cranes, except that the cylinders are usually fixed vertically on the *inner* wall of the building, and in most cases only one lifting cylinder is used, the cranes raising a certain maximum load, separate cranes being fixed where required to take the heavy loads. The valve boxes and levers are the same as before described. Separate cylinders are used for swinging the jib, which is applied in same way as in the case of the wharf cranes. The working cylinders are placed at the top floor near the top of the jib—the stroke of the rams is usually made in the proportion of 8 to 1. In many instances, especially for light loads, the jibs are swung by automatic apparatus, by means of springs and an arrangement of levers and balance-weights, on plans designed by the Author some years since.

Hydraulic Foundry Cranes.

Cranes for lifting foundry ladles, and for other purposes, are constructed somewhat in the same manner as the post cranes described at p. 22, except that they are direct-acting, the stroke of the ram

being equal to the maximum height to be raised. The cylinder is placed vertically, and forms, with the ram, the post of the crane. The jib is made horizontal, and is strutted and provided with tie rods at the *top* side; it is attached to the ram head by means of an iron frame, the foundry ladle or pot is hung upon four wheels, and travels on rails fastened to the jib plates. The jib is extended to the back of the crane, on which a sliding counter-balance can be racked in and out as necessary. The ladle is hung on trunnions at each side, and is swung by the usual worm and worm wheel gear. It is racked in and out from the post as required by means of screw- and wheel-gear. The ladle is raised to the height required by the direct stroke of the ram, without the intervention of chains or any other gear.

It is swung by turning the ram in the cylinder; this is accomplished by screw and worm wheel-gear. All the operations can be directed by one man. The diameter of the rams depends upon the load to be raised; in some cases this is as much as 20 to 30 tons; a margin is allowed in case an unusually heavy lift is required at any time. The cylinder is provided with a large base-plate, which is strongly ribbed to the barrel. It is made of sufficient strength to resist the thrust of the jib; the ram is treated in the same manner. The valve-box is usually in the form of a chamber with two ports provided with a slide-valve; the shape of the pressure port is made taper, and rather wide in proportion to the length, to allow the pressure to be gradually applied, and so avoid shocks. These cranes are simple in construction, and perfectly safe in working. They can be adapted for light weights as well as heavy ones, and admit of many modifications to suit special cases. They are very suitable for unloading goods from vans and trucks when the height to be raised is but small; when used for this purpose, the general design is altered in several particulars.

Johnson and Ellington's Patent Double-Power Hydraulic Crane.

Drawing No. 12 shows a form of double-power crane which is in extensive use and merits notice. A single sheave is mounted on the head of the ram working in the cylinder, and the ends of

the chain passing over the sheave are attached to the smaller sheaves, one on the one side and two on the other. Either of these sheaves can be locked so as to form the fixed end of the chain passing over the ram. When one end is fixed the crane will lift a greater load than when the other is fixed. An ordinary hydraulic crane, constructed to lift 25 cwt. 40 feet in height, would for each lift use the same quantity of water, whether the load were 25 cwt. or 10 cwt.; but in this crane, with the same size of ram, it would only make half the stroke, using half the water, when lifting the lighter load. It is specially adapted for working high warehouses where the loads vary, as, without increasing the size of the apparatus, a 10-cwt. or 15-cwt. crane is made to lift 20 cwt. or 30 cwt. half the height. In cases where heavy goods are landed on to a quay, and light goods only warehoused in the top floors, the saving effected by this system is very great; and the lighter loads can be lifted at an increased speed. Between sixty and seventy lifts per hour is an ordinary rate of lifting.

Thornton's Double-Chain Sack Hoist.

Drawing No. 13 shows an improved sack hoist fixed in the roof timbers of the building, and arranged for one chain to lower while the other is hoisting. There are two hydraulic cylinders and rams with chains led over multiplying sheaves on the ram-head and corresponding sheaves on the cylinder end, and on to a chain wheel which, in its turn, actuates the two winding drums. The working valve is arranged to open each cylinder alternately to the pressure and exhaust, thus raising and lowering each chain. With one of these hoists as much as 1400 quarters of grain have been stored in a warehouse 60 feet high in ten hours' time.

Cranes for Coal Lifting.

The cranes used for lifting coals usually have a radius of about 21 to 25 feet, and lift a coal bucket containing 10 to 15 cwt. about 40 feet high at each lift. At the large floating vessels belonging to Messrs. Cory and Son, in the Thames, the average annual

work is equal to $1\frac{1}{2}$ million of tons, from about 1800 ships; the maximum in one week being 53 ships, discharging 47,160 tons of coal. Three cranes will discharge a ship of 900 tons of coal in $7\frac{1}{2}$ hours. On one occasion $872\frac{3}{4}$ tons were cleared in $4\frac{3}{4}$ hours, equal to $61\frac{1}{4}$ tons per crane per hour, delivered and weighed. At another time *one* crane discharged 480 tons of coal in $8\frac{1}{4}$ hours, equal to $58\frac{1}{4}$ tons per hour. On another occasion, *one* crane discharged 64 tons in 59 minutes, equal to 65 tons per hour. The Author believes the above is the largest amount ever done by hydraulic cranes for this class of work. These cranes multiply 8 to 1, and give a high working result, both as to speed and economy.

The coal skips used are 3 feet 6 inches in diameter, by 3 feet 3 inches deep, and hold $14\frac{1}{2}$ to 15 cwt., according to the kind of coal.

The cost of working the machinery, including maintenance and repairs, but exclusive of interest and the men in the "hold," is about 1*d.* per ton lifted; taking all expenses into account, the cost may be put at 4*d.* to 6*d.* per ton.

The above data as to the amount of work done will only apply to places of like magnitude; for smaller quantities the cost will be proportionately higher. For ordinary lifting of coal the cost may be put at 6*d.* to 7*d.* per ton.

The Largest Coal Cranes in use are those at Gallion's Wharf, in the River Thames, where a discharging berth has been recently constructed from the designs of Mr. Henry Adams, M. Inst. C.E. This installation, known as the "Albert Dock Coal Hoists," contains several movable cranes somewhat similar to that shown in Drawing No. 8, but so arranged that loaded trucks may pass under them, to economise the quay space. The cranes have a variable radius from 25 to 50 feet, a turning power through $1\frac{1}{4}$ revolutions, and a lifting capacity of 30 cwt. through a height of 60 feet. When luffed up to the minimum rake the cranes stand 70 feet above the rail level, and they run on a 16-feet gauge. This arrangement results in great economy of working, as the whole frontage may be occupied with ships, the barges lying outside them. The cargo is delivered into trucks or barges with equal facility, capstans and traversers being provided for handling the trucks. The coal buckets are of steel, holding 18 cwt. of house coal, and proportionately more of Welsh or less of gas coal. Ships of the largest size

are discharged with equal despatch, as six or more cranes can be brought to bear upon them at the same time. The weighing is automatic, upon the principle of fluid pressure, transmitted to a gauge with a dial divided to show hundredweights and quarters. Owing to the magnitude of the tonnage dealt with, and the economical necessity for the utmost expedition, the major part of the coal coming to the port of London (say five millions of tons annually) is weighed on the cranes as lifted, or otherwise in transit between ship and barge. To avoid dispute between the colliery and the merchant, the weighing is mostly recorded by a body of officials known as "Meters," under the orders of the "Committee of the Coal Meters' Office," and the cranes are tested periodically by their consulting engineer. In other cases, private Meters are employed.

Hydraulic Travellers for Workshop and Mill Purposes.

The application of hydraulic power for raising and moving loads by means of travellers, is attended with great advantage. There are several modifications in the arrangements. In all cases, the girders, and the gantry upon which the traveller runs, are constructed in the usual manner. The girders should always be made of wrought iron, either in the plate, lattice, or box forms. The spans vary from 20 to 50 feet; when, however, this latter span is exceeded, it adds much to the expense of the apparatus. For details of this portion see p. 145, under the head of Travellers Worked by Steam. For foundry and factory purposes, the lifting machinery consists of a short stroke cylinder multiplying 4 or 6 to 1, according to the height to be raised; it may be placed either vertically or horizontally according to which is the most convenient for the particular case; the traverser is generally worked by another hydraulic cylinder. The details of the machinery do not much differ from that used for cranes. The water-pressure pipes are carried along the gantry on one side; the pipes are connected in about 8 feet lengths by ball and socket joints folding up or extending according to the position of the traveller. The pipes are suspended from light wheels which run upon the rails of the gantry; each of the lengths of pipe is fitted with a chain to act as a guard, and prevent it from being

extended too far and so strain the joints. The pressure is generally 700 to 750 lbs. per square inch, and is supplied from an accumulator. It may be noted this class of machine cannot be used with economy unless cranes or other like apparatus have to be worked.

Travellers without Traversing Motion.—When these are for small height of lift, say 5 to 5 feet 6 inches maximum, and when it is only required to lift at the centre part of the traveller or at each end, as in the case of purifier covers at a gasworks, a direct-acting ram and cylinder is provided, and by means of a cross-head of steel, and chains, the load is raised. It may be arranged with inverted cylinders fitted with pistons and steel rods, the lifting chains being attached direct to the piston-rod and to the load. For the purpose of raising light loads with a larger range of lift, a cylinder and ram with movable pulleys and chains is used. This acts independently of the main lifting gear.

Hydraulic Power Companies.—In London, Liverpool, Hull, and other towns, the above companies supply water under pressure for working cranes, hoists, small engines, and other apparatus. It has proved a most successful system. The charge for the water is very wisely made upon measurement by meter of the actual amount used; the tariff is very moderate, and offers a great inducement to many to use hydraulic power for various purposes. The convenience, as well as the safety, in using this power can hardly be sufficiently insisted on; there is absolutely no fire risk, no nuisance arising from heat of pipes, as in the case of steam power, no leakage from the pipes and apparatus. As no expensive plant, with pumping-engines, boilers, and tanks are necessary, no large amount of capital is sunk, and therefore no heavy charges for interest and repairs, &c., are incurred. The pressure is always available both by day and night, thus saving the attendance and expense of engine-drivers and stokers where pumping engines and accumulators are employed. The pressure given is from 700 to 750 lbs. per square inch. It may be remarked as to the measurement by meter, no difficulty is experienced when using Schönheyder's patent positive meters, which the Author believes to be the most reliable for measuring water under the heavy pressures supplied by the Public Hydraulic Power Companies. A full description and drawings of water meters will be found in the Author's book, Part I., on 'Pumps and Pumping Machinery' (Spon).

CHAPTER III.

HYDRAULIC HIGH-PRESSURE LIFTS AND HOISTS.

Hydraulic Wagon Hoists.

These are used at the various railway depôts and other places (see Drawing No. 19). They consist of a platform about 22 feet long by 9 feet wide, capable of taking a loaded railway truck. The table is constructed of wrought iron, powerfully framed and riveted together, and provided with a 4-inch timber platform, on which are fixed the rails for the trucks to run on. At the top of the table or platform vertical trough irons are fixed, lined with gun-metal, about 12 inches long at top and bottom; these form the rubbing-guides, and at the top of these a cross girder is riveted; chains are attached to this, and pass over the wheels to the counter-balances on either side. The vertical iron guides are stayed diagonally.

Two rams are provided, one being 9 inches diameter, and the smaller one 6 inches diameter, by 20 to 25 feet stroke, to suit the height to be raised; the heads of both rams are securely fixed to the lower part of the iron framing of the platform. The rams work in cylinders with bored heads, and are provided with leather collar-packing; the cylinders are sunk in a well formed as before described.

Two rams are used to raise the maximum load, but in lowering, the large ram, by a special arrangement of the valve-gear, is allowed to discharge, and the smaller one returns the water to the accumulator under the pressure of the descending load of the table, &c. To raise the empty table the small ram only is used. It will be seen by the employment of two rams of different areas, power is available according to the requirements, and much water is thus saved. The rubbing-guides may either be riveted on to wrought-iron framing, and placed *above* or *under* the table or platform, to suit the

special circumstances of each case. They must each be 12 inches long, and at least 6 feet 6 inches apart, in order to form a sufficient guide to the table. The guide-bars are of cast iron, one being placed at each side of the table; they are planed on the faces.

The valve gear is the same description as used for the cranes. Self-acting stopping gear at the top and bottom is provided in all cases. The load raised, including the weight of the wagon or truck, is from 16 to 19 tons; the pressure usually employed is 750 lb. per square inch.

LIGHT TRUCK HOISTS.—A modification of the above is also used in warehouses and factories to carry up trucks containing light goods. The rams are small in diameter; and, to give them sufficient strength, they are made either of tubular or solid wrought iron or steel. The guide-bars may be of 4 inches by 4 inches T-iron, one being placed at either side of the table; the rubbing-guides are either attached to wrought-iron framing placed *above* or on the *underside* of the table. This must depend upon circumstances; if head room is available, and a counter-balance is to be provided, the former plan is most convenient, but when the space above the top floor is to be kept clear the latter system is adopted. These rubbing-guides should be about 6 inches to 9 inches long, and should closely fit the guide-bars; two should be provided on each side, the distance between the lower and upper guides should be at least 3 feet 6 inches to 4 feet, when placed *under* the table, and when *above* the table 6 feet to 6 feet 6 inches apart. This is for the purpose of giving a perfect guide to the table, and to prevent any side strains being thrown on to the ram. Counter-balances in these cases are not generally provided when heavy pressure is at hand.

The valve motion is of a very simple kind. The table or platform is made of wrought iron, with hard wood floor, or it may be made of boiler-plate $\frac{1}{4}$ to $\frac{1}{2}$ inch thick. Self-acting stopping gear is attached to stop the lift at the top and bottom, and so prevent accidents from over-running.

Lifts for Passengers, for Hotels, etc. (Drawing No. 21).

When lifts and hoists are worked on the high-pressure system the machinery consists of a long cylinder of cast iron, with a hollow ram either of cast or wrought iron, working in the same, having a stroke or rise equal to the whole height to be lifted. The ram cylinder is contained in a well sunk in the ground; it is either lined with brickwork or by an iron cylinder. The ram cylinder is suspended from the base stone, and hangs quite free in the well; it is jointed together by flanges, in about 9 feet lengths, and well bolted together. To the top of the ram the cage or ascending room is attached; this room is formed of strong iron framing well braced together, with a roof of plate iron $\frac{1}{4}$ inch thick, to prevent accident from weights falling on top of the same; the floor is of wood, carried on a frame of wrought iron, to which it is bolted; the sides are lined with wood, and all parts are firmly bolted together.

Two cast-iron guide bars, which are planed on their faces, are fixed to stone templates, which are built in the side walls; four rubbing-guides, lined with gun-metal, are fixed at the top and bottom of the cage. The guide bars should be set dead plumb; the rubbers should not have any side play. The rubbing-guides are kept up to their work by spiral springs. Counter-balances are not often provided for lifts when worked under heavy pressures. In other respects they are the same general construction as the low-pressure lifts, described more in detail at p. 60.

The valve box is fixed in the basement, it is attached to an endless rope passing through the cage, and this enables the attendant to operate the lift from the inside of the cage. Self-acting stopping-gear is provided to stop the lift at the highest and lowest points. Special appliances are also provided to save accident from any cause.

These lifts, being direct-acting, have no gear of any kind overhead. They are absolutely safe, noiseless in action, and can be worked with great ease. They are, however, only applicable where an accumulator is used, or where water under heavy pressure can be obtained from an accumulator or the Hydraulic Power Company's mains.

ELLINGTON'S PATENT HYDRAULIC BALANCE LIFT (Drawing No. 22).

This consists of an ordinary direct-acting ram lift combined with a hydraulic balance. The object of the balance is to equalize the weight of the moving parts of the lift, without the use of overhead gear and balance weights. It may be arranged for either a high or a low working pressure.

The high-pressure balance consists essentially of two fixed rams, arranged vertically on a common centre line with a cylinder sliding on them, the cylinder having an internal pocket tube dividing it into two compartments, and thus isolating the two rams. The upper and smaller working ram may be put in connection with supply or exhaust mains, as required. The lower, or displacement ram, is in constant communication with the lift cylinder, and the water between them having no means of escape, forms a direct communication between the lift ram and the moving parts of the balance, any motion of the one being transmitted to the other. The area of the displacement ram being always a multiple of the area of the lift ram, the stroke of the balance is necessarily a corresponding fraction of that of the lift, the multiplying power being arranged to meet the circumstances of each case.

The cylinder of the balance is loaded with weights, which assist the working ram in generating any required pressure in the displacement ram. The pressure in the displacement ram is that produced in the lift cylinder by the combined weight of moving parts and load, divided by the area of the ram. When the lift is unloaded it is that due to the weight of parts only. The weight of the loaded balance cylinder is such as to generate a slightly less pressure than the latter in the displacement ram, and thus to nearly balance the moving parts. The area of the working ram is such that when under the working pressure it will, with the assistance of the loaded cylinder, produce a pressure in the displacement ram exceeding the highest produced in the lift cylinder.

The controlling valve of the lift consists of a two-ported slide valve, the pressure port having two outlet branches, each with a screw-down spindle-valve, so that the connection may be made through either one of the branches. One branch is connected

directly with the lift cylinder, and the other with the upper or working ram of the balance. The connection to the lift cylinder is an auxiliary one, only being intended for use in case it is required to work temporarily without the intervention of the balance. The controlling valve is operated by means of a hand-rope passing through or alongside the lift cage, so that the valve may be worked from the cage. It is also provided with tappets at the top and bottom, which engage with a striker on the cage, so that the valve is operated automatically as the lift reaches either limit of its travel. When the lift is required to ascend, the controlling valve is opened to pressure, the water passing into the working ram forcing the moving cylinder down, and thus driving the water from the displacement ram to the lift cylinder. When the lift is required to lower, the valve is opened to the exhaust; the working ram is thus relieved from pressure, and the lift, loaded or unloaded, is able to overcome the loaded balance cylinder, causing its ascent, and the spent driving water from the working ram through the valve to the exhaust.

The economy of the balance arises from the fact that the portion of the pressure in the lift cylinder due to the weight of parts is produced by the weight in the balance, the pressure water having only to raise the load, besides overcoming the friction of the apparatus.

The balance, as described above, also serves another purpose, independent of the balancing. In high lifts, worked from a high-pressure supply system, such as that of the London Hydraulic Power Company, it is found that the diameter of the lift-ram is determined by its function, as a column which gives a larger area than required for raising the combined live and dead load with the given pressure. In such cases an ordinary balance, consisting of chains and weights, cannot be used. This introduces an additional source of waste in simple direct-acting lifts, which is avoided in the balance lift, owing to the fact that any required increase of the lift-ram may be met by a corresponding increase of the displacement-ram without materially affecting the working-ram, which alone determines the consumption of pressure water.

In order to make up for any loss by leakage or otherwise of the displacement water between the balance and the lift, a charging

valve is provided, which, when opened, admits water from the pressure mains into the lift direct. It is arranged on the base of the balance, and the valve lever is set so as to be depressed by the balance cylinder if it should fall below its normal working limit, which it will do in case of any loss by leakage or otherwise of the displacement water. The depression of the charging valve lever opens the valve, and the loss is thus made up automatically.

The lift cylinder is provided with a weighted relief valve, which prevents any undue rise of pressure in the cylinder. Provision is also made for this valve to be opened automatically, in case of any over-stroke of the lift, the water escaping, and any further rise of the lift prevented.

When intended to work from a low-pressure system, such as ordinary town's mains, the design of the balance is slightly modified, the upper ram being replaced by a fixed cylinder, the moving cylinder itself forming the ram, working into the fixed cylinder, into which the pressure is admitted and exhausted as described for the high-pressure lift.

Hydraulic Passenger Lifts at the South London and Suburban Railway.

(Made by Sir W. G. Armstrong, Mitchell and Co., Limited.)

At each of the stations of this underground railway the passengers are raised and lowered at the station by two hydraulic lifts, each of which acts entirely independently, and is capable of raising fifty passengers. The lifts about to be more particularly described are those at the Monument Station of this railway; most of the others are of similar dimensions. The lifts are placed in a circular well 25 feet in diameter, side by side, one side of each ascending room or cage being flat, and the other part follows the contour of the well. The cage of each lift is 22 feet long and 9 feet wide and 11 feet high. The water pressure for raising the load is supplied by pipes from the pumping station placed about 3 miles distant, the pressure being 1200 lbs. per square inch.

The two hoists in the well are quite independent of each other.

The lifting machinery is placed vertically at each side of the shaft. It consists of multiplying cylinders made of steel, the stroke being in the proportion of three to one. The cage is lifted by six steel-wire ropes passing over large pulleys at the top of the lift, four of the ropes being in connection with the hydraulic cylinder, and two with the counter-balances. The valve-box is fitted with piston-valves and the usual controlling gear, lever rods, and ropes.

The ascending rooms are powerfully framed in steel, and lined with mahogany and pitch-pine panelling. They are lighted by gas. Safety apparatus is provided for each cage.

The cages are guided by iron bars fixed to the sides of the well; rubbing-guides are attached to the top and bottom of the cage-framing. Counter-balances are provided, which are each attached to two steel-wire ropes. The total height raised is 67 feet, and the time occupied is about three-quarters of a minute.

The pumping engines and machinery are, as before stated, situated at Stockwell, about three miles from the Monument Station; the pressure pipes are laid through the tunnel, from which, at the several stations, the power is taken to work the lifts. At the present there are only five stations, each one having two hydraulic lifts, representing a total of ten lifts to be supplied. There are three coupled engines, which have sufficient power to meet any demand that may come upon them. They are of the usual Armstrong horizontal compound (non-condensing) type; the pumps are double-acting, and are placed at the back of the cylinders, and are operated direct by the engine piston-rods; the cylinders are high-pressure, 15½ inches diameter, and low-pressure, 29¾ inches diameter, both having a stroke of 20 inches. The speed worked when under full load is 45 revolutions per minute. The pressure of steam used is 90 lbs. per square inch. The indicated H.P. of each set of engines being 140. The water is pumped into an accumulator which is loaded to give 1200 lbs. pressure per square inch. An extra accumulator is provided at the Elephant and Castle Station in addition to the above; this is for the purpose of equalizing the pressure. The waste water is discharged into air vessels at each station, and from thence returned in pipes to the pumping station.

Goods and Luggage Lifts.

These are usually worked by short-stroke cylinders multiplying by movable pulleys, fixed either vertically or horizontally, as described at p. 18, and shown in Drawing No. 6. The cages are made of iron, strongly braced with wood floors, bolted to the lower part of the iron framing. They are fitted with an endless rope, which passes through the cage to the valves. Self-stopping gear is also provided to prevent accident. When a heavy pressure of water is used, counter-balances are usually supplied. The guide bars in this case are 3 inch or 3½ inch T-iron, either fixed to timbers or direct to the walls of the building. Safety gear is attached to the top of the cage to save accident in case of the chain breaking; it is advisable to have the top of the cage made of wrought iron plate, the same as the last described.

This class of lift is not suitable for passengers, on account of the unavoidable risk that always attends the use of chains or ropes; the Author recommends the long ram lifts *in all cases for passengers,* as the only kind in which *perfect security* can be obtained, and is of opinion that any lift cage raised by chains, or ropes, should not be allowed in use.

Coal-Loading Apparatus (Drawing No. 23).

This machinery for loading coal from trucks into ships at the river side was designed and executed by Sir W. G. Armstrong and Co. The trucks are run on to a lift table, or platform, having rails fixed on top, and being of a size to easily take the largest truck to be lifted. The wheels are stopped by wedges to prevent any movement during the time of making the lift. The platform is attached to a hollow ram, working in a cylinder: when hoisted to the required height, the truck is tipped by a small hydraulic ram, fitted with trunnions, and the contents shot out of the truck down an iron shoot, into the ship's hold. A pair of doors is fixed across the mouth of the shoot to control the flow of the coal, and stop it when required. An hydraulic crane of the same type as before described is used to form a conical heap of coal, to save breaking it

in discharging into the ship, sufficient being lowered in buckets taken from the mouth of the shoot to effect this. The framing for carrying the crane jib, coal shoot, and machinery for raising and tipping, is of wrought iron, strongly braced and riveted together. The machinery for working the crane consists of short stroke cylinders combined with movable pulleys, as before described; the jib is swung by two rams and cylinders of short stroke connected by a chain to a grooved wheel placed at the bottom of the crane post. It is a most rapid method of transferring coal from railway trucks into vessels or craft. This apparatus, as well as all previously described under this head, were introduced by Sir W. G. Armstrong and Co. They perform the work in an admirable manner. The weight of each truck with load of coal is about 19 tons: the trucks are tipped at about an angle of 45°; the height of the lift from the dock or quay level is about 37 feet. The cage, or platform, which receives the trucks is raised by two hydraulic rams, one about 11 inches diameter, and one 6½ inches diameter. In lifting two rams are used; but in lowering the larger ram is allowed to discharge and the smaller one returns the water to the accumulator under the pressure of the descending table and wagon, by which means the water is economised.

CHAPTER IV.

SUNDRY MACHINERY WORKED BY HIGH-PRESSURE HYDRAULIC POWER.

Capstans.

These useful apparatus are shown in the Drawing No. 14. They consist of two or three hydraulic cylinders with ram pistons working direct on to one crank shaft. They are fixed immediately under the capstan-head, to which they give motion. The valve gear and levers are of much the same construction as the cranes, and are fixed in a convenient place. Guide pulleys are provided at various spots, so as to be able to draw the trucks in any direction required. Some discussion has taken place as to the shape or contour of the head; the Author considers it is advisable to use them with a slight taper only.

Brotherhood's Patent Three-Cylinder Hydraulic Capstan.—The three-cylinder capstan shown on Drawing No. 15 is one of the best applications of Brotherhood's engine, and the capstan itself is worth notice, as it was the first constructed in which the engine and capstan were made self-contained on one bed-plate. The engine is coupled direct to the capstan-head. An important feature of three-cylinder single-acting engines is that the moving parts are only subjected to strain in one direction, and in the Brotherhood engine advantage is taken of this in a particularly neat arrangement of the connecting rods, which all work on to one crank pin, and are always in compression. The simplicity of the construction of this capstan is shown by the fact that it can be taken to pieces and put together again in less than half an hour.

Capstans are largely used by the railway companies and others for hauling wagons in the goods yards; a train of twelve to twenty loaded wagons can be drawn by a single capstan. The controlling valve is actuated by a treadle. The engine working direct on to the capstan, as in Brotherhood's system, reduces friction to

a minimum, and the absence of gearing and alternate strains renders a breakdown a very rare occurrence.

The use of capstans ought to become general in private works; the cost is not half that of horse work, and when hydraulic power is otherwise used the first cost is not high.

In cases where it is undesirable or difficult to construct a pit (generally about 4 feet deep) under the capstan, Mr. E. B. Ellington, M. Inst. C.E., has introduced an improvement by which the capstan is lifted bodily about 2 feet above the ground line without breaking any pipe joints, thus giving access to the various parts, while the working of the engine can be tested in its raised position. This is shown in detail in Drawing No. 16.

Swinging Dock Gates.

Hydraulic apparatus as before described is used for this purpose, with chain gear from same to open the gates, as shown in Drawing No. 17. The work is done by a small hydraulic engine working with a crab motion, with a barrel to coil the chain on; it is somewhat similar to the engines used for capstans described above. The details of the apparatus vary to suit special cases. The three-cylinder engine is also very suitable for such purposes, and can be easily applied.

In some instances the gates are opened and closed by short rams and cylinders, with chain gear as described for the cranes (see Drawing No. 18), this system is often employed in the case of graving docks, and in other cases direct-acting rams and cylinders are used. The cylinders are sometimes made of steel for large gates; they are about 2 feet 5 inches diameter, and the ram 1 foot 9 inches diameter, with a stroke of 25 to 26 feet, for gates for spans of openings of 80 feet. Apparatus of this kind is only used for large dock gates.

Swinging Apparatus for Bridges.

For heavy iron bridges a very useful application of hydraulic power is made. The pin upon which the bridge turns is raised by

hydraulic power to take the pressure off the rollers and leave all perfectly free. Hydraulic cylinders with chains and wheel, the same construction as for the cranes, are employed for working, or small hydraulic engines with wheel and rack gear fixed to the under side of the bridge may be used. When the weight of the bridge is considerable, the whole dead load is not taken off the centre pin, on account of the dangerous oscillation that might take place; usually only about two-thirds is taken, leaving one-third on the friction rollers.

The largest bridge of this kind is the one across the Tyne at Newcastle, made by Sir W. G. Armstrong and Co.; it is about 280 feet long and weighs upwards of 1200 tons. The Author has seen this bridge swung open, allowing one vessel to pass, and close again in three minutes, with the greatest ease; it is a magnificent piece of work, and is controlled in opening and closing in the most rapid manner, especially considering the large weight dealt with.

Turn-Tables for Railways.

Hydraulic power is applied to these in much the same way as above. The turn-tables can either be worked by cylinders as before described, or by the small hydraulic engines working in a rack or wheel fixed to the centre pin. They are much to be recommended, as at nearly all large railways high-pressure hydraulic power is available. The application of the power machinery in this case is so simple it does not require any detailed description.

Railway Platforms (Movable).

Hydraulic power is used for working the above. One of this class of apparatus has been at work daily at the Paddington Station of the Great Western Railway for some years. The moving platform is for the purpose of giving communication between two longitudinal main platforms. Others have been fixed since the above; the principle is, however, the same. They are very useful where an occasional communication is required transversely with a central

platform at a terminus. They can be moved out ready for use in less than two minutes; when not wanted, they are drawn under the main longitudinal platform.

There are many other purposes for which high-pressure hydraulic machinery can be usefully employed, such as for corn warehousing, applications to gunnery, opening of sluices, working wharf shear-legs, &c. In nearly all these cases the machinery is of a very special kind; in some instances is not often required, and as the description of this machinery would take up too much space here, further detail has not been entered into.

CHAPTER V.

HYDRAULIC CANAL BOAT LIFT.

This machinery is for the purpose of raising boats at Anderton, on the river Weaver, from one level to another; it was designed by the late Mr. Edwin Clark, M.I.C.E., and was the first apparatus of this kind used for such a purpose.

The difference of height between the river and the canal at this point is 50 feet 4 inches. The lift was designed to raise the barges direct through this height, and thus save expense and time in passing through several locks. Drawing No. 20 shows the arrangement.

There are two lifts; the barges are raised and lowered when floating in a trough of water, it being arranged that the barges descending in one lift should help to raise the barges ascending at the other lift. The size of these troughs is 15 feet 6 inches and 75 feet long; they will hold either one of the largest or two small ordinary barges; these latter carry 40 tons, and the largest about 100 tons. The sides of the troughs are constructed of wrought iron, 9 feet 6 inches deep at the centres, and 7 feet 6 inches at the ends. The depth of water in the troughs is 5 feet. At each end of the troughs there are lifting gates, and syphons at the side to regulate the depth of water required. The weight of each trough, with the water and barges, equals 240 tons, or a pressure of $4\frac{3}{4}$ cwt. per square inch on the ram.

The rams are 36 inches diameter, hollow castings made in three lengths jointed by internal flanges and well bolted together. The details of the rams and cylinders are much the same as the ordinary hydraulic lifts for heavy pressures already described.

The well cylinders are about $1\frac{1}{4}$ inch thick, and 5 feet 6 inches in diameter, put together in sections and flanged at the joints.

The Accumulator to work the lift has a ram 1 foot 9 inches

diameter, by 13 feet 6 inches stroke, and has a capacity equal to one of the main rams for a stroke of 4 feet 6 inches. The two rams are in communication by a 5-inch pipe fitted with an equilibrium valve for opening and closing the communication between them. The pipe from the accumulator to the ram is 4 inches in diameter.

The weight of each trough, &c., is the same when an equal depth of water is in each. Suppose the heavier one descending with 5 feet of water against 4 feet 6 inches in the ascending trough, the valve between the rams being opened, the lighter one will be raised to within, say, 4 or 5 feet of the top. The rest of the lift is done by the pressure from the Accumulator. It is essential that the depth of water in the *ascending* trough should never be more than 4 feet 6 inches, the extra water being drawn off by the syphons; there are twelve of these to each trough. About $\frac{11}{12}$ of the entire lift is done by taking a layer of water 6 inches deep out of the *ascending* trough; this is about 15 tons' weight, the $\frac{1}{12}$ to complete the lift is performed by the accumulator. Each ram and cylinder, with its trough, is in turn an accumulator to the other, and does its own work in lifting and lowering.

TIME.—The lift will take up and bring down two barges in 8 minutes. Had this been done by a series of locks, it would take 1¼ hour to 1½ hour for each barge to pass through.

Each trough can be lifted separately by the engine and accumulator. This is, however, a slow operation, and takes about half an hour. The lift is capable of transferring sixteen barges per hour—eight up and eight down. The barges can be raised the whole height, equal to 50 feet 6 inches, in three minutes.

In the event of one ram and trough only being used, viz., a single in lieu of a double lift, a much larger pumping engine and machinery would be required.

The details of the guides, valves, &c., are much the same as for heavy hydraulic hoists. The advantage possessed by this apparatus over locks, is the small amount of water used, and the time saved.

The staff of men required is five. The total working expenses are £10 per week.

The total cost of the lift work was £29,463. The work was done in 1872, when iron was much higher than at present; and with many modifications that would be made in one at the present time

(1892), it would cost considerably less. This apparatus is a most ingenious application of hydraulic power. The late designer stated that he would another time use a single ram and trough, worked by a large accumulator; one-third of the cost would be saved, and as much work done per day as with the double lift.

Clark and Standfield's Special Hydraulic Apparatus.

In addition to the hydraulic canal lift, above described, and shown in Drawing No. 20, designed by the late Mr. Edwin Clark, there are several other ingenious applications of hydraulic power to special cases that merit notice here. As most of the apparatus of this firm is of a special character, it has been treated under a separate head.

Messrs. Clark and Standfield have had very large experience in this class of apparatus. Most of the special hydraulic machinery now about to be described, is unique of its kind; it is hoped the detailed particulars will be acceptable to the reader. A short description is given in each case, sufficient to explain the general system; more minute detail could not be entered into, being beyond the scope of the work, and forming, as it would, a book in itself. The designers of the machinery described in this section have the merit of working in a new field, having carried out some stupendous works in a very ingenious and highly satisfactory manner.

Differential Hydraulic Apparatus.

In this apparatus any two weights can be balanced hydraulically, and may be made to ascend and descend at will by the opening or closing a valve.

Let any two equal or unequal weights be supported on hydraulic presses, and the size and number of the presses so adjusted that the weights are in equilibrium, or rather, that one of them slightly preponderates. If we suppose the lighter of the two weights supported on three (or more) presses, and one of these presses be shut off, so that the weight rests only on two, the result will be that the weight will now descend. On opening the communication with the third press it will again ascend, and this may be repeated at will, only a press full of water being wasted at each stroke. As

the third press may be of small size, and the waste of water may be supplied from an accumulator, this forms a very convenient movement for the raising and lowering of guns, as shown at Drawing No. 24, or for similar purposes, such as lift-bridges, &c.

The Accumulator is constructed with three presses, A′, B′, A′, and three plungers, A, B, A. They are loaded with the weight, W, which is adjusted to balance the gun, G, supported on the press, C′, and its ram C. The plungers, A A, are of such dimensions that, when loaded with the weight, W, and connected jointly with the ram, C, they just balance the weight of the gun, G, which is therefore free to be raised or lowered without any power except that necessary to overcome friction. When this equilibrium is obtained, a small additional weight, W′, is added on the accumulator, which consequently descends, and elevates the gun, G, to its full height. All this time the plunger, B, is out of action, and is merely connected by a pipe with the supply reservoir. If it be desired to cause the gun to descend, the tap, D, in connection with the small plunger, B, is opened, so as to place all three plungers in communication. The pressure being now distributed over all three plungers instead of only two, causes the weight, W, to ascend, and the gun, G, to descend. If it be again required to raise the gun, G, it is only necessary to close the tap, D, and the weight of the accumulator coming only on the two plungers, A A, again causes the gun to ascend as before; the water under the small plunger, B, being, as before, allowed to return into the supply reservoir. In this way the gun, G, may be raised and lowered at pleasure by turning the tap, D, and the only power wasted is that of the small plunger, B, which is made of such size as to be just sufficient to overcome the necessary friction. It is evident that the same effect of obtaining a slight variation of pressure in the accumulator may be produced by either allowing the weight, W′, to rest on the weight, W, or holding it off therefrom; and this may be done in many ways. For example, it may be effected by the central plunger, in the manner indicated by the dotted lines, X. Thus, if water under pressure is introduced below the central plunger, and the weight, W′, raised, the gun will descend; but if the weight, W′, is allowed to rest upon the weight, W, the accumulator will descend, and the gun again rise.

It is obvious that, by the arrangement described above, there need be no waste of power except such as may be just sufficient to overcome the friction of the leathers, &c., and one accumulator may be made to operate all the guns in a large fort.

In a second arrangement, they support a weighted accumulator, not on a single press, as is ordinarily the case, but on a group of three, four, six or more presses, with a suitable arrangement of valves for throwing any one or more of them out of action. Let us suppose the object to be lifted to be a bridge or an ascending platform, with a varying load of vehicles or people; the accumulator is so weighted that when all the presses are in action, the platform slightly preponderates, and descends. If it be desired to raise it, one only of the presses is thrown out of action: the accumulator now resting on fewer presses, exerts a greater pressure, and the platform consequently ascends. If the load be a heavy one, more of the presses are successively thrown out of action, until the weight of the accumulator, resting on a smaller number of presses, or it may be on only one remaining press, exerts sufficient pressure to raise the platform and its load. By this way very little power is wasted, as the quantity of water consumed at each lift is adjusted to the load to be raised. But there is still further gain to be obtained by employing a similar group of presses under the platform itself. In this case, if the load be a heavy one, it will drive back the water from a certain number of presses into the accumulator under full pressure, where it will be available for another ascent, and the greater the descending load, the greater will be the number of presses which will be enabled to return their power to the accumulator, the others discharging their water to waste. This system is particularly applicable to the case of ascending and descending platforms at railway stations, or at a high-level bridge, where the load, be it of men or of vehicles, is very variable. By this means a large proportion of the power used in raising the vehicles at one end of the bridge is afterwards restored to the accumulators by their descent at the other end. The same system, when applied to hydraulic cranes for the lifting of variable loads, enables the power to be increased two, three, four, or six times at pleasure.

Messrs. Clark and Standfield employ a somewhat similar arrange-

ment to ensure that any load, such as a ship, or bridge, or a canal lift, when lifted by the simultaneous action of two or several presses, shall remain horizontal at all times. This is effected in the following manner:—Whatever be the number of presses supporting the bridge or other object to be raised or lowered, the same number of presses are grouped together under a single accumulator of the same weight as the load to be lifted. Thus, in a bridge, there might be two presses under each end of the bridge. These four presses would be connected separately to four similar corresponding presses under one and the same weighted accumulator. By this arrangement, whatever be the inequality of the weight of the bridge, a perfectly uniform movement is secured in each of the four groups of presses, and the bridge must at all four corners ascend and descend with the same velocity, and preserve its horizontal position at all points of its ascent or descent. This is shown in Drawings Nos. 25 and 26. This arrangement is eminently suitable for transferring railway trains, either with or without their locomotives, from a low to a high level, or *vice versâ*, and for surmounting abrupt prominences where inclined planes would be very costly in construction and expensive in working.

The compensation is effected by a fixed syphon, S, supported by the tank, T. The accumulator, in addition to its weighted load, W, carries a compensating water-tank, M, which rises and descends with it. The syphon, S, dips into this tank, and as it descends the tank becomes filled with water and its weight increased; and when it ascends, the water flows back again through the syphon, S, and the load is diminished so as to preserve the equilibrium at all points of the stroke. If a be the area of the plungers, t the area of the tank, and m the area of the compensating tank, the proper size for this tank, when adjusted for perfect equilibrium, will be $20m = 2a + (2a \times \frac{m}{t})$.

The Accumulator shown in Drawings No. 25 and 26 is formed with several plungers combined into a group, so that when it is desirable to cause several rams to ascend at the same time through equal distances, as in the case of lifting the two ends of a bridge or a canal lift, a railway train or gun platform, the several rams employed may be supplied with water under pressure from separate

plungers, and all the rams be thereby caused to ascend through uniform distances. *a*, *b*, *e*, *d*, and *f* are the six rams and plungers of the accumulator. Four of the plungers, *a*, *b*, *e*, *d*, are connected respectively by pipes with four hydraulic presses at the corners of the bridges, and the accumulators are so loaded as to descend and to raise the bridge when the weight rests on these four plungers only; *c* and *f* are used for lowering the bridge, and whenever they are placed in connection with the other four plungers, the accumulator rises and the bridge descends.

On the other hand, when the communication with the two presses, *c* and *f*, is cut off, the whole weight of the accumulator comes on *a*, *b*, *e*, *d*; the four plungers descend, and the bridge is raised. Since these four plungers are all independent, and are connected independently to the four presses at the corners of the bridge, all four corners must rise at exactly the same speed and to the same level. When a vessel desires to pass, the bridge is either submerged under water to a sufficient depth to allow the vessel to pass over it, or lifted into the air sufficiently high for the vessel to pass beneath it. In a similar way, a train or gun platform may be raised and lowered by two or more rams supplied with water under pressure from separate cylinders of an accumulator such as above described, and thereby ensure the raising and lowering of the platform in a horizontal position.

Hydraulic Wagon Hoist (Drawing No. 27).

This is designed by Messrs. Clark and Standfield, for raising railway wagons from a lower to a higher level, for contractors' purposes. It is worked by an accumulator capable of lifting one, two, or more wagons at each lift, to a height of 30 or 40 feet, and is calculated to effect a great saving in time and horse power. The accumulator may be the same as shown at Drawing No. 25. The press is shown at AB, at an angle of 45°. Whenever C carries a wagon, D, or other load, it may be raised up to a higher level at E, where the wagon is removed and replaced by an empty wagon, which descends to a lower level; the power used in raising the platform and empty wagon being again given back to the accumulator as they descend. The accumulator is so arranged as to have different powers.

Thus, when all six presses are connected with the empty platform, it descends; if two of these presses be cut off, and the weight of the accumulator be allowed to rest on the remaining four, the pressure is sufficient to raise the platform with the ordinary load; if three of the presses, *d*, *f*, *b* (Drawing No. 26), are shut off, and the weight allowed to remain on the other three, it will raise a wagon with a heavier load; and if four of the presses are shut off, *a*, *b*, *d*, *e*, and the weight of the accumulator allowed to rest on the remaining two presses, it will be in a position to lift the heaviest load; and all these changes may be made on the instant by opening the valves *g*, *g*.

Hydraulic Grid (Drawings Nos. 28 and 29).

Messrs. Clark and Standfield have had large experience in hydraulic machinery for raising vessels, and have introduced an hydraulic apparatus for docking vessels, which is especially suitable for the shores of tidal waters. In this grid, the presses are placed directly beneath the vessel, whereas in the ordinary hydraulic lifts the vessel is supported on girders. The economy effected by this and other arrangements is such that the designers estimate the cost of such docks as not exceeding, under favourable circumstances, about £5 per ton weight of vessel lifted, which is very greatly less than the cost of any other dock whatever.

Drawing No. 28 shows an end elevation of the grid, with a vessel raised upon it. A A are the presses, B B the rams, C C the pontoon or grid. In Drawing No. 29 the grid is shown in plan, with the skin-plate removed to show the construction, and with the outline of a vessel dotted upon it. The backbone is there shown as consisting of two parallel wrought-iron girders the whole length of the dock; there are also on each side an intermediate longitudinal girder and an outside girder. These are crossed at a right angle by a number of transverse girders, or ribs. Five of these transverse girders are shown in pairs, and these are placed over the bilge presses.

In Drawing No. 28 sliding bilge-blocks, D D, are shown, and at the ends of the girders side shoring frames, E E, to keep the vessel upright. The rams as they ascend carry up the grid, with the vessel upon it, and when it is at its highest level it is supported

there on struts or pawl-legs, which are by preference jointed to the grid at the top, and which were at first suspended in a horizontal position, but which are now allowed to fall vertically, so that their bottoms rest upon the shoulders of the presses or upon convenient tables attached thereto. These pawl-legs, or pillars, are shown in their vertical position in Drawing No. 28 resting upon the collars of the presses, and are marked F. There may be as many legs as there are presses, or in some cases twice as many. As soon as the weight rests upon these struts, the rams are lowered into the presses to prevent them from rusting.

The presses are divided into three groups, for maintaining the level of the grid in the manner usual with hydraulic lift docks, each group taking as nearly as possible one-third of the weight. The vessel is thus supported on a triangular bearing, and can be listed laterally or longitudinally in any direction without unequal strain. The pipes leading from the three different groups are indicated by dotted lines leading to the valve house, where they are concentrated into three sets, marked H, I, K (Drawing No. 29). The grid is guided as it rises and falls by means of grooves and tongues, or rollers working in fixed vertical columns at the sides or ends. The columns also act as fenders, and are marked L L in all three drawings. At the inner side of the dock, these grooves or tongues are secured to the wall, as shown at M M (Drawings Nos. 28 and 29). In some cases it is preferable to incline the presses at an angle, in which case the grid rolls or slides up an inclined plane. The presses in Drawing No. 28 are shown thus inclined, and leaning towards the inner wall. In place of the struts, or legs, F F, it may be sometimes preferable to employ a framing of trestlework with diagonal braces, and this may be constructed like a skeleton box, with four sides; in which case it is formed of timber, so that it may be conveniently floated into its place when the vessel is raised. Drawing No. 28 shows an end elevation and a side elevation of one of these skeleton presses.

The vessel is brought over the grid at high water, the pumps are set in action, and the grid and vessel are raised well above high-water mark; the legs or trestles are placed in position, and the whole is lowered until the grid rests on the legs. The rams are now lowered down into their presses, and allowed to remain there while the vessel is being cleaned or repaired.

Hydraulic Canal Lift.

Messrs. Clark and Standfield have also made many improvements in canal lifts, similar to the one erected by the late Mr. Edwin Clark at Anderton, in Cheshire, described at p. 42, and, with Mr. Edwin Clark, have designed some of larger dimensions for the French and Belgian Governments. The large size of the presses required for such purposes (6 feet 6 inches in diameter, with 60 feet stroke) brings into prominence a loss of power which is generally overlooked. Let us suppose two such presses joined by a tube and working without any friction; the two pistons would immediately assume the same horizontal level. If now one of them be forcibly depressed 30 feet, so as to elevate the other 30 feet, it will be found that a weight of 40 tons will be required to balance the weight of the extra water in the elevated press, and this 40 tons of power is necessarily wasted every time a vessel is lifted or lowered. Messrs. Clark, Standfield, and Clark have, however, entirely obviated this waste of power, which is common to all hydraulic presses, by an ingenious compensator, which maintains perfect equilibrium of the presses in all positions, and enables them to be used without any loss of power except that due to friction.

Hydraulic Canal Lift, designed for the French Government by Messrs. Clark, Standfield, and Clark, for Fontinettes, near St. Omer (see Drawings Nos. 30 to 35).

A, lifts; B, rams supporting the lifts; C, presses; D, pipes communicating with both presses; E, valve; F, rod for working the valve; G, permanent aqueducts; H, gates closing the aqueducts and the lifts; I, dry reception chamber for the lift to descend into; J, accumulator; K, valve house.

This canal lift has all the latest improvements, and is remarkable for the large size of the hydraulic rams, which are 6 feet 7 inches in diameter, and have a stroke of about 45 feet. In this lift the varying weight of the water in the presses is perfectly compensated in every position, and there is loss of neither water nor power beyond that necessary to overcome the friction of the leathers and guides.

Comparing this arrangement with that at Anderton, described at p. 42, the loss of water is in the ratio of 1 inch to 5 feet, that is, $\frac{1}{60}$; and by comparison with an ordinary lock, the loss of water is only as 1 inch to 45 feet, that is, less than $\frac{1}{500}$; of course, the area is assumed to be the same in each case. An important point to notice is that, when *loaded* barges are descending and *empty* ones going up, a volume of water equal to the difference between the weights of the ascending and descending barges is raised and passed into the upper canal.

Besides a second series of lifts which have been designed for the French Government, two series of lifts of somewhat similar dimensions have been designed for the Belgian Government, the first of which obtained the Government prize awarded after public competition. This series of lifts was designed for passing a canal over a range of hills between Charleroy and Brussels, where water is not obtainable. In fact, this important feature of the hydraulic canal lifts enables the engineer to carry canals over dry table-lands, where there is no water supply, and where canals with locks would be impracticable. It will also render the construction of canals possible in many districts, and much saving will be effected in the construction of locks, and saving of time in transit of the barges as well as the saving in water.

In describing these canal lifts, the Author believes he has brought to the notice of many engineers and others a most ingenious application of hydraulic power which is very little known. He, however, believes there is a grand future before it, and too much praise cannot be given to the designers of such powerful apparatus.

Clark and Standfield's Hydraulic Lift for Railway Trains.

This apparatus is shown in Drawings Nos. 36 to 38, and is a novel application of their patent hydraulic system, which may probably solve a difficult problem in railway work, especially in the vicinity of large towns, or where the trains of different companies may arrive at the same point at high and low levels. Much saving of time and cost would be effected by the proposed plan, which also has the advantage of being perfectly safe, free from all complication

in working, and also a very economical application of power. A large amount of money has been wasted in forming inclines, which are not only expensive, but dangerous to work, and require excessive engine power. This is illustrated by the approaches to the Thames Tunnel, the Ludgate Hill Station, and the high-level stations of the London, Chatham, and Dover Railway; the Snow Hill incline, and many similar places. This evil may be entirely obviated by the hydraulic system of balancing one train against another, or preferably by balancing the train by a differential compensating accumulator, with automatic valves, to ensure the horizontality of the system. Such a system, designed by Messrs. Clark and Standfield, is illustrated in Drawings Nos. 36, 37, and 38. Drawing No. 36 shows a side elevation, Drawing No. 38 an end elevation, and Drawing No. 37 a plan of a hydraulic train lift (which may be made of any length), suitably guided and supported on a number of presses. The trains are balanced by a differential compensating accumulator (not shown in the drawing), on the system described before; so that the train or accumulator may be made to preponderate, and be raised or lowered at will. The train is kept level by automatic valves, as before described. When the height is moderate, this operation may be easily performed in less than one minute, as in an ordinary passenger lift. Before the train descends, the opening is protected by powerful hydro-pneumatic buffers, as in the Drawing, which shows one in position, and one swung back. Similar buffers are provided at both ends of the lift. This system could be cheaply and readily applied both to tunnels and high-level bridges, and would be very suitable for river ferries. By a similar compensating system applied to balancing platforms for railway passengers, a railway tunnel might be constructed in the London clay at a low level beneath streets and houses, without interfering with any surface property, except at the stations, the trains being raised to the high-level systems when outside the city area.

CHAPTER VI.

GENERAL REMARKS AND DETAILS OF HIGH-PRESSURE HYDRAULIC MACHINERY.

The following details and data refer to the High-Pressure Hydraulic Machinery described in the previous pages; it is collected in this section to save repetition, because most of the matters hereafter named apply to the various apparatus described.

Valves.—Slide valves working over ports are not usually so good as piston mitre valves; when, however, they are adopted, the pressure port should be made V-shape, to allow the power to be applied gradually, the valves and faces must be made of gun-metal, and the work must be of the best kind. To relieve the heavy pressure on the back of the valve, a balanced valve is sometimes employed with much advantage. No sharp bends should be allowed, either in the passages of the valve boxes or in the pipe connections leading to and from same. The size of the pipes to and from the valve boxes must be carefully proportioned to save undue friction. No rule can be given for this, as it much depends upon the pressure used and the circumstances of the case.

Pipes.—When placed outside are usually carried underground in close trenches, and must be well protected from any chance of injury both from frost and the passage of vehicles. Those passing through warehouses should be carried on brackets on the walls, and be provided with small cocks at various points to drain them in case of frost; they should also be protected by clothing from the effects of the weather. Valves should be placed at suitable points to shut off the water when not required in certain directions, and also for closing in case of fractures to save stoppage to the whole length of

the main. Air cocks are provided in suitable positions to keep the pipes free from air, and to ensure a perfect circulation of the water.

CHAINS should be carefully examined once per week, and changed once per month. Several spare chains should be kept for use in case of emergency; only the best short-link tested crane chain should be used. The chains when taken off should be passed through the fire and annealed, and turned end for end when next put on the crane or hoist; the wear is thus taken upon another part of the link.

SKIPS or BUCKETS for unloading coal, sand, and like material, may be made of steel plates, and usually hold from 7 to 12 cwt. Where one or two cranes are used, the Author recommends 7 cwt. skips, two being provided for each crane; they should be mounted on three swivel-friction wheels, running on turned steel pins, carried in carriages bolted to the bottom of the skips.

THE WATER used for hydraulic apparatus must be clean, and should in most instances be drawn from a receiver or tank; all gritty matter will sink to the bottom; the suction pipe should be placed 1 foot or more from the bottom of the tank, to prevent any dirt or grit being pumped and passed through the machinery. In all cases the tanks should be closely covered at the top and protected at the sides, to protect them from the weather.

The Quantity of Water used by a 30 to 35 cwt. crane to lift goods from the hold of a ship to the wharf level (allowing for the bulwarks of the ship), is about 9½ to 10 gallons; and to lift the empty chain from the wharf and ready to swing over the vessel, say, 6½ gallons; or, say, 16 to 16½ gallons as a total for the lifting, but exclusive of swinging the crane.

The Cost of Pumping Water under Pressure.—Taking a pressure of 750 lbs. per square inch to be the usual maximum used, the cost is about 8*s*. to 10*s*. per 1000 gallons when pumped upon a large scale, such as at docks, &c.; when there are only three or four cranes, say, 10*s*. to 12*s*. per 1000 gallons. All cost is taken into account—fuel, wages, repairs, and superintendence, interest on capital, and every working expense.

THE TOTAL COST of lifting by hydraulic power may be taken at 1·26*d.* per 100 foot-tons; this is an average taken from the returns of seven large places; 15 per cent. is allowed in the above amount for interest and depreciation. This is provided the cranes are in constant work; it would be safe to take, say, 2½*d.* to 3*d.* per 100 foot-tons for ordinary work, and for small places a much higher rate.

COMPARISON OF COST WITH HAND POWER.—The average working of hand-power cranes requires eight men at the handles to lift 10 cwt. working twenty sets per hour, or 10 tons raised 40 feet, at a cost for labour of 2*s.* 8*d.* per hour. By the hydraulic cranes, one man at 4*d.* per hour—thirty-six lifts of 15 cwt. each made per hour; or 27 tons 40 feet high, at a cost of 4*d.* Hand power, say, 3¼*d.* to 4*d.* per ton; hydraulic, ¼*d.* per ton for labour. This average is taken from the work actually done at one of the large London wharves.

SPEED OF LIFTING.—In 30 cwt. hoists and cranes it is about 4 feet to 6 feet per second; wagon hoists with 13 to 14 ton trucks, say, about 22 feet in 15 seconds. One 30 cwt. crane can discharge from a ship to the wharf level when working eight hours, 460 to 470 tons. Bags of seed can be lifted and warehoused a total weight of 560 tons to a height of 75 feet in about eight hours; special arrangements are made for the slinging of such goods.

GENERAL REMARKS.

High-pressure hydraulic machinery can be most usefully and economically employed at railway depôts, large docks, wharves, and warehouses, and especially where a number of cranes, hoists, and other apparatus, have to be worked at some distance from the engine power. In the case of docks and warehouses, this enables the proprietors to have the engines and boilers at one spot, in a fire-proof building, if necessary, and where one set of men can attend to the whole of the boilers and pumping machinery actuating the accumulators. Where hydraulic machinery is employed, the fire

companies do not increase the rates of insurance; the danger of possible explosion from several boilers (which would be necessary for steam power) is avoided; and wherever extra cranes are required, an attachment can be made to the main pipe with small outlay. Hydraulic cranes are well under control; in fact, all hydraulic apparatus has had such careful attention from several designers and makers, that the Author considers such apparatus are more easily and safely controlled than any other class of lifting apparatus in use, and he also believes can be more safely and expeditiously worked. One great advantage of hydraulic machinery is that no wear and tear takes place when the cranes and lifting machinery are out of action—the power at this time is stored up in the accumulator ready for the next time of working. This is a great consideration at a dock, wharf, or railway depôt, and other large places of like kind, where the work is intermittent; the cranes can be started at any time, and are ready to raise their maximum load.

CHAPTER VII.

LOW-PRESSURE HYDRAULIC LIFTING MACHINERY.

THIS class of hydraulic machinery is principally used in private factories and public institutions; it is worked on the following plans, viz.:—

1. By head of water from a tank fixed at the highest point of a building, or any other elevated place.

2. Where the water companies and town corporations will allow it, pressure may be taken from the public mains, and the expense of erecting a large tank saved. This is not, however, always advisable, as in case of an accident at the waterworks, or any unusual demand upon the mains, sufficient pressure cannot be obtained to work the lifts.

3. Where several short-stroke lifts or cranes have to be worked, a small engine pumping water into an air-vessel may be advantageously used; the water is pumped under a pressure of 100 to 200 lbs. per square inch. The air-vessels have to be specially made to ensure they are absolutely tight, and cause no leakage of the air. A small pump is employed to keep up the pressure of the air.

The great advantage of working the lifts from a tank is that the user is quite independent of all machinery, excepting the power required (in large places) to re-pump the water into the tank. No water in this case is wasted, and the lifts can be used at night without any attendant being required for the pumping machinery, as in the case of high-pressure hydraulic lifts. The cost of the machinery is far less, and there is very little chance of leakage, on account of the lower pressure in the pipes. The wear and tear and consequent repairs to the machinery are small, the leather collars, when properly fitted in, last for years, and the machinery not being subject to the same shocks as in the high-pressure lifts, there is little liability to

get out of order. The Author, having designed a large number of this class, may, from the experience of some years, state that no accident of any kind has taken place to anyone using such lifts.

Passenger Lifts (Drawing No. 21).

The construction of these is in some respects much the same as the high-pressure lifts, described at p. 30, except that all the parts are made of less strength, and vary slightly in some of their details.

A well is sunk in the centre of the lift-shaft, rather deeper than the height to be lifted; when constructed in the London district—where gravel and sand are usually met with near the surface—the water is shut out by sinking cast-iron cylinders; these should be 3 feet in diameter, and in about 6 feet lengths, internally flanged together and well bolted. The first cylinder is provided with a cutting edge at the bottom, and when the clay is reached it is driven from 2 to 3 feet into it, to form a joint, and prevent the water rising under the cylinder. The rest of the well may be lined in brickwork, 4½ or 9 inches thick, and built in Portland cement; the thickness of the lining of the well depends upon the nature of the ground. Great care must be taken to keep the well perfectly vertical.

The cylinders in which the ram works are suspended in the well, the stroke of the ram is equal to the height to be raised; it works through a bored head fitted with a gland and leather collar; this head is seated on and bolted to the foundation stone.

The cage, or ascending-room, is attached to the top of the ram, and is made of wrought-iron, well framed together; the top is ¼-inch wrought-iron plate; the floor is of oak, and the sides pine-boards, grooved and tongued, and bolted to the iron frame at the top and bottom part of the cage.

Cast-iron planed V guide bars are fixed on stone templates built in the walls at each side of the lift-hole; they must be erected perfectly plumb, and must leave very little side-play at the rubbing guides, which are fixed at the top and bottom of the cage on either side.

To the top of the cage are attached two wrought-iron plate wings, to which the counter-balance chains are attached on either side. These chains work in grooves in the side walls, and pass over two cast-iron chain-wheels fixed on the top of the side walls, and so to the counter-balances, which work in iron guide bars fixed on each side of the grooves in the walls on either side of the lift-hole.

The valve-box and gear to work the lifts is fixed below the floor, and self-acting stopping gear is also provided to stop the lift at the highest and lowest points to prevent accident. Every possible provision is made to ensure perfect safety.

Hydraulic Passenger Lift to raise 10 cwt. (Drawing No. 21).

The construction of this lift is given as an example to show the system which is recommended for adoption for lifts with 7 inches to 10 inches diameter rams, some of the dimensions being subject to adjustment to suit the size of the ram used in each particular case.

The ram is 9 inches diameter, and 63 feet stroke, capable of raising 10 cwt., worked by a head of water of 103·5 feet = 45 lbs. per square inch. A large number of these lifts have been constructed to the designs of the author, and have been successfully worked for some years.

The *Cylinders.*—These are 11 inches diameter inside, and are made of flanged pipes faced at the joints. The barrel is 1 inch thick, and the flanges 1¼ inch; they are bolted together with eight bolts 1 inch diameter; the length of each section of the cylinder is about 9 feet, the lower cover must be made 2 inches thick, and be strongly ribbed. The cylinder is attached at the top to a large casting 3 feet high, which rests upon the foundation stone; it is bored at the top, and recessed for the packing-leather, which may either be U or hat-shaped. A gland is fitted at the top of a less depth than the leather, and so leaves a space for it to rest in, and gives facilities for removing the leather without drawing out the ram. The gland is bolted to a top flange, and made watertight. The base of the top casting is planed, and the stone carefully chiselled true and dead level for it to rest on; it will be seen if this head of the cylinder, which also forms a base-plate, is made absolutely

level, the ram will work perfectly vertically, which is a most essential thing in these lifts.

The *Ram* is 9 inches diameter, made of cast or wrought-iron; in the former case it is made $\frac{3}{8}$ inch thick, and in about 9 feet lengths, screwed together by internal and external V screws of six threads per inch; they must be made a perfect fit, and each length of ram should be made interchangeable; no jointing material must be used, but the dead fit at the threads depended on. In the case of wrought-iron or steel tube rams, they are made about $\frac{3}{8}$ inch to $\frac{7}{16}$ inch thick, and are jointed by screwed thimbles, forming a junction of at least 6 inches deep. The bottom of the ram in each case is closed water-tight by a cast-iron faced flange, and well bolted by turned studs, or it may be screwed in. The ram is attached to the cage by connecting it with a bored boss contained in a frame bolted to the lower part of the wrought-iron framing of the cage; it is also provided with extra safety bolts of steel, which are attached to a lower part of the ram.

The *Cage*, or Ascending Room, is made of wrought-iron, well framed together as described. The size for hotel or hospital work is 7 feet × 5 feet 6 inches × 6 feet 6 inches high; the way in which the counter-balance chains are attached to the sides of the cage has been described. The floor is made of oak planks, $1\frac{1}{2}$ inch thick, grooved and tongued, and well bolted to the lower frame of the cage; the sides are either of oak or deal boards, $\frac{3}{4}$ inch thick, grooved and tongued, and bolted to the top and bottom frames of the cage; they thus help to stiffen it, and increase the rigidity without adding to the weight. The working rod or rope passes through the cage, thimbles of turned gun-metal being provided to prevent friction; the lift is thus stopped and started by the attendant only from the *inside* of the cage; this prevents any interference of other people, and saves accidents. Rubbing-guides lined with gun-metal made in the form of piston guides are attached to the cage on each side at top and bottom; they should be at least 8 inches long, and be provided with a cup-piece at the top of the liner to take the grease.

The *Guide-Bars*.—One is fixed at each side of the cage; they are of cast-iron with V faces, which are planed; they are also planed on the facing pieces at the back; they are put together in 8 feet to 9 feet lengths, and bolted at about 4 feet 6 inches centres to stone tem-

plates let into the wall. These templates are tooled to a true face, and made absolutely plumb. Great care should be exercised in the fixing of the bars to ensure that they are dead level each way.

Two Counter-balance Weights are provided for the lift, one being placed at each side wall at the back of the cage; these weights are made about 2 feet wide and 5 inches thick, and a length sufficient to give the weight required; they have planed grooves at each side, and slide in 2½ inch L-iron guides, placed in recesses in the side walls, and are provided with pockets at the top part to permit of adjustment.

Chain Wheels.—Two grooved wheels, 3 feet 6 inches diameter, supported on brackets, are placed on top of the side walls; the chains are ⅝ inch diameter, one end of each being attached on either side of the projecting jaws in the cage, and the other by means of a link to the counter-balance weight. It will be seen by this arrangement, which was introduced by the Author about twenty-five years ago, that no gear of any kind is placed overhead, the chains and balances working in recesses left in the side walls of the well-hole. These recesses are covered by boards 1 inch thick at the front. In case of either of the connections between the cage and the counter-balances breaking, the weight would fall to the bottom on india-rubber cushions, and thus all liability of doing personal injury is avoided. At the level on which the chain wheels are placed a strong floor is provided, so that, in the event of a fracture of any part of the wheels or their enclosure, it would fall on the floor, and would do no damage to the cage or its occupants.

Valve-Box and Gear.—One valve-box fitted with ram or piston-valves is placed near the head of the cylinder, and by an arrangement of levers, &c., is made to start and stop the lift as required.

The pipes are made of a diameter to suit the pressure of water passing through; in this lift the inlet pipe is 4 inches diameter, and the outlet 3 inches diameter. An air-vessel is placed in the outlet and inlet pipe near the cylinder to assist the easy working of the lift. The tanks for working these lifts are placed on top of the walls of the well-hole; they are of cast-iron, and of sufficient capacity to contain one and a half days' supply. The waste water in most cases is received in a lower tank, and pumped up as required to the

top tank to keep up the supply; this may be done by a small steam-pump of the single cylinder or duplex type. By this means the cost of working the lift is represented by the small cost of pumping.

These lifts for low-pressures are made with 8 inches, 9 inches, or 10 inches ram; they cannot be economically used unless a head of water of at least 50 to 60 feet is available.

Hydraulic Passenger Lifts at the Underground Station of the Mersey Railway at Liverpool.

These lifts are for the purpose of raising and lowering passengers from the level of the railway to the street. They were designed and made by Messrs. Easton and Anderson, Limited, London. Three lifts are employed at the James Street station; they are worked on the low-pressure system by the fall of water from a tank placed 120 feet above the level of the street, which gives an effective head of 176·5 feet above the waste-pipe from the lift. The lifts are on the direct-acting continuous ram system, the rams being made of steel tubes, 18 inches exterior diameter, $\frac{1}{2}$ inch thick, and 76 feet 4 inches stroke; they are screwed together in lengths by interior thimbles 6 inches long, with V threads, eight per inch. A $1\frac{1}{2}$ inch diameter bolt passes from the top to the bottom of the rams for extra security, in addition to the bolts which hold the rams at the top to the cage. The cylinders in which the rams work are 21 inches internal diameter, and $1\frac{1}{2}$ inch thick; they are formed of cast iron flanged pipes in 12 feet lengths with faced joints, and are held together by sixteen $1\frac{1}{8}$-inch diameter bolts and nuts. At the top the cylinders are bolted to a bored head, which is recessed for a leather collar, at the lower part of which a base-plate is provided, and which is bolted to the foundations. The ascending rooms, or cages, are 19 feet 6 inches by 16 feet 6 inches, and 10 feet high; each room has an area of 165 square feet, they are lined with panelled teak, they are each capable of carrying one hundred passengers. The lift shafts are 21 feet by 19 feet, partly excavated in solid red sandstone, and partly enclosed in walls built in Portland cement.

The cages are attached to the top of the rams by steel bosses having radial arms forged out of the solid, the ram is secured to the

boss by four 1¼ inch diameter turned bolts and nuts. At the lower part of the cage, two powerful wrought-iron girders are provided; the boss and cross-arms are attached to each of these girders. On top of the girders eight wood joists, 10½ inches deep, are bolted, and on these the 1¼ inch teak floors of the cages are carried. The girders project at each side beyond the cage, and to their ends the counter-balance chains are attached. Four rubbing V gun-metal guides are bolted to the top and bottom of the cage, two being fixed at each side. The cages are each guided by four V-faced steel bars or rails in 15 feet lengths, which are attached to wood brackets standing out from the walls into which they are built. There are two counter-balance weights to each lift, and four points at which the chains are attached to the cages. The chains are 1⅛ inch diameter, and weigh 13·3 lbs. per foot. Each of the counter-balances weighs 7,620 lbs. The valve-boxes are fitted with slide-valves, and are provided with the usual starting and stopping gear.

The supply tanks, placed on the top of the building, are equal to a capacity of 10,000 gallons, the water-pressure on the ram is 76 lbs. per square inch. When the tank is full it affords a storage capacity for twelve journeys. The water is pumped up by three duplex pumping-engines, designed and made by Messrs. Easton and Anderson, Limited, each engine works two pumps, and by the automatic action attached run fast or slow, according to the requirements of the work.

The steam cylinders are 11 inches diameter, and 20 inches stroke. The pumps are double-acting, 7½ inches diameter, and the same stroke as the cylinders. Each of the engines is capable of pumping up from the lower to the upper tank 30,000 gallons of water per hour. The steam is supplied by three 6 feet 6 inches diameter and 11 feet long boilers, of the marine return-flue type, having 3 inch diameter tubes. All the pumping machinery is placed 27 feet below the upper booking hall of the station.

The supply-pipe to each lift is 7 inches diameter. The speed of the lifts is 120 feet per minute, or about thirty-eight seconds from the lowest to the highest level.

SHORT-STROKE RAM LIFTS (Drawing No. 39)

Are made in much the same way as the above, except that the cage is dispensed with, and a table or platform is attached to the head of the ram. Two iron guide bars are fixed at the sides, and rubbing guides to the table. It is advisable in most cases to fix counter-balances to take the weight of the table and part of ram. The wells, cylinders, &c., are as before. The valve arrangement is similar to the other lifts, but smaller as to the pipes, &c. Self-acting stopping gear is provided to stop the lift at the highest and lowest points.

This class of lift is very suitable for banks or any place where valuables have to be stored. The entrance in this case to the safe or strong room is by the lift only; the top plate of the table is made of wrought iron, and fits into an iron frame at the top floor, similar to a safe door; a patent lock, throwing out eight bolts into this iron frame, is fitted to the under side of the plate; the pressure is left on the ram all night, the gear for regulating this being shut up in a recess, and fitted with an iron safe door and patent locks. Where heavy safes containing documents for daily or hourly reference are required, the safes are fitted with wheels and run on rails on top of the lift table; rails are also laid in the vault or strong room, by which means the safe is run off into an inner strong room if required; the lift then rises, and brings down any others, and the books, specie, &c.

SHORT-STROKE RAM LIFT (Drawing No. 40).

The general details of this lift as to ram, cylinder, &c., are the same as the last named. The guides are fixed at the *back*, to enable the table to rise *above the level of floor or street* at the top, so as to allow casks or other goods to be rolled off at the level of the carts. A lift of this kind is very suitable for a brewery or wine cellar, where the table rises to the level of the public way, and where no fixings for guides can be obtained at the *front side of the lift* at this level. There are many other modifications of this kind of lift suitable to special requirements, but as they are seldom used, further detail is not necessary. The great advantage of lifts (as Drawings Nos. 39

and 40) are perfect safety, noiseless action, and total freedom from vibration; the speed is also under absolute control, and they cannot be overloaded. The wear and tear is very small, even when the work is constant. The cost of water is not a large item, and is hardly worth taking into account, considering the saving of labour. All the parts are simple and free from complication, and there is nothing likely to get out of order.

The friction of "ram lifts" is small, especially when the leather collars are well fitted. When well designed and properly constructed it does not exceed 5 per cent. Packed glands of any kind are to be avoided; friction is much increased by their use. The lubricant used should be good sperm or mineral oil—vegetable or lard oil should never be used—and the ram must be kept very clean.

Short-Stroke Cylinder Lifts (Drawing No. 41).

These lifts are very suitable for raising goods, coals, luggage, food, and other light goods. The most simple plan of construction is an open top vertical cylinder fitted with piston, having a rack attached to the top side; this rack gears into an iron pinion, and by means of a train of wheels, rotary motion is given to a drum, and the requisite amount of rope or chain is coiled. The stroke of the cylinder, and the number and proportion of the wheels, are regulated by the height to be lifted. However carefully made, there is much friction in this class of lift, and a good margin must be allowed to ensure sufficient power and to spare to do the work. The bucket or piston should be fitted with two leathers; hemp or metallic packing cause more friction. All the teeth of the wheels should be pitched and trimmed; the back and sides of the rack should be planed, and work against a turned friction wheel fixed at top of the cylinder to form a guide; the working pinion should be provided with shrouds turned on the edges, which also rub on the faced front edges of the rack. Great care should be taken that all the work is perfectly true and of the best kind, otherwise much power will be lost by undue friction. In well-constructed machinery the friction may be taken at about 25 per cent. To provide a margin, it is advisable to allow even more than this.

Short-stroke cylinders with chains and movable pulleys (see Drawing No. 6) are also sometimes used, and especially where the working cylinders must be placed horizontally. More friction takes place with this kind of gear than the one above described, but it may be materially reduced by attention to the quality of the work and proportion of the parts.

The cages are made in much the same manner as those for high-pressure lifts, except that all the parts can be much lighter. Gear rods or ropes pass up the lift hole, to enable the lift to be worked from any floor. Counter-balances are fitted to these lifts; they are made flat in shape, with planed grooves to run in two L-iron guide-bars. The weight of the balances is less than the cage, to give sufficient power for the cage to fall, when empty, by its own gravity, and keep the ropes taut on the drums. Self-acting stopping and safety gear is also provided to prevent accidents. Wire rope is the best to use for raising the goods. In some cases two ropes are used, working upon separate drums; if one rope breaks, the other is able to take the load safely, and so avoids accident to the cage and its contents.

Lifts of this kind are very suitable for private houses, to carry up food from the kitchens; also coals, &c., to the various floors. The cost of water is not a large item, considering the great saving in labour and time effected. They are not liable to get out of repair, and are easily worked. The speed can be regulated, load controlled, and the attendant cannot either work the lift more rapidly or take more than the *maximum weight.*

Parcels Lift.

Drawing No. 42 shows a very useful application of Brotherhood's three-cylinder hydraulic engine to small lifts, introduced by Mr. E. B. Ellington. The engine is reversible, and carries a grooved pulley, round which is passed a rope, attached at both ends to the lift boxes, and having an adjustment for keeping the ropes taut. One box ascends while the other descends, thus effecting a great saving in time and power. The boxes can be worked by hand, by

means of a second rope passed over the head sheave. A high speed can be obtained; the lifts are quite silent, and easily controlled. The cages or boxes may be made entirely of wood; the guides may be wood or L-iron, fixed to the framing. The lifting medium may be either hemp or wire rope. The construction is so simple that the drawing fully explains, without any further description.

Brotherhood's Patent Three-Cylinder Hydraulic Engine.

Brotherhood's three-cylinder hydraulic engine is a great improvement upon the ordinary Armstrong type of oscillating cylinders. A really reliable hydraulic engine was much wanted, and as Mr. Brotherhood's has stood the test of many years' constant work, he is to be congratulated on his success. The working parts consist only of the three pistons and connecting rods, one crank, and one rotating balanced valve and spindle which fits into the driver, and is turned direct from the crank pin. There are no glands, stuffing-boxes, or oscillating joints, and the wear of all the parts is taken up automatically, so that nothing has to be tightened up. The engine is made reversible if required, simply by a modification of the engine valve and the addition of a controlling valve to alter the direction of the flow of water into and out of the engine. Mr. E. B. Ellington has effected some useful improvements in these valves, by which certainty of action is secured. The working parts are all protected; the engine occupies very little space, and will work up to 200 revolutions per minute.

These engines have been adopted for lifts and hoists, and for working the hauling gear for sliding *caissons*, and for controlling the sluices in the extension at Her Majesty's Dockyard, Chatham, and for other like purposes.

Low-pressure Hydraulic Power can also be employed for organ-pumping, working small engines, turning (small) lathes and other machines, and to a variety of purposes too numerous to detail here. The author is of opinion that the application of this power is still in its infancy, and if water companies would be more liberal in

their arrangements with regard to the use of water direct from the mains, engineers would turn their attention to the design of many kinds of apparatus where water power of low pressure could be usefully employed—this more especially refers to machines for domestic use, and in large establishments, where saving of time and labour are so essential. The great advantage of self-acting water power apparatus of this class is—there is no necessity for a steam boiler; the consequent dirt and trouble, as well as expense of fuel, &c., for working, is saved; and the apparatus not only works silently and without vibration to the surrounding building, but is more easily controlled than any other class of machine. At no very distant day, all houses of any size will not be considered complete unless fitted with machinery of this kind. The particular attention of architects is therefore drawn to this subject, and the Author trusts he has made the matter sufficiently clear to be of practical use to them.

With regard to lifts worked on this system, there are many modifications made to suit special circumstances; the general design does not, however, differ sufficiently to require description in detail. The Author ventures to advise architects and other users to bear in mind that hydraulic machinery of all kinds must not only be well designed, but well made; the unfortunate struggle after cheapness has induced too many, to their regret, to adopt poor machines, which not only always give trouble, but in the end cost more on account of the frequent repairs necessary.

PART II.

HYDRAULIC PRESSING MACHINERY.

CHAPTER I.

HYDRAULIC PRESSES.

HYDRAULIC PRESSES being so much used for pressing various descriptions of goods and materials, the Author proposes to describe their practical application to various purposes. As most of the presses are on the same general principles, he commences with the description of one suitable for most kinds of work; it is an average size as to the diameter and stroke of the ram, and with some minor alterations can easily be made suitable for many purposes; in cases where the working pressure is less, the thickness of the cylinder may be reduced, as well as the strength of the other parts.

10-INCH HYDRAULIC PRESS, FOR 3 TONS PER SQUARE INCH (Drawing No. 43).

This consists of a ram 10 inches in diameter, the stroke varying from 1 foot 6 inches to 7 feet 6 inches, according to the sort of goods to be pressed. The cylinder is $5\frac{1}{2}$ inches thick, and is cast with a round bottom; it is bored out for 24 inches in depth from the top, and at 6 inches (from the top) has a recess in which is sunk a ∩ leather collar. The pressure of water coming upon the thin edge forces it against the ram, and so prevents leakage. The cylinder rests on a cast-

iron base, having a hole in the centre; this casting has four holes for the columns at the outer edges, the head is cast off the same pattern, the hole in the centre being filled up. The columns supporting the head should be of best scrap wrought-iron, $3\frac{1}{2}$ inches in diameter, with double collars forged on at each end; these slip into recesses in the head and base, and have plates fitted over them and secured by bolts to keep them in position. The whole strain is taken on the collars, which should be forged solid, and turned between the shoulders; the head and base are also faced at these points, to ensure a perfectly even bearing, the collars also being turned where they seat. The table is about 4 feet 6 inches to 5 feet by 3 feet 6 inches to 4 feet wide; the top is planed, and the bottom has a bored boss, in which the top of the ram fits; the table is not bolted to the ram, and in case of fracture can be renewed at much less expense. The base should rest upon a timber frame, bedded on a brickwork or concrete foundation, the cylinder hanging *free* in the middle; it must not touch any part of the foundation at the bottom. The metal of which the cylinders and the rams are cast must be very tough, and specially selected for the purpose; each must be cast with a head or runner, and the metal run vertically; common iron is useless for the purpose. All the bearing parts of the table, head and base, should be machined to ensure even pressure at all parts. The leather collars must be of the best oil-dressed leather, carefully made, and put in by skilled people. When this has proper attention, the leathers will last for a long period without taking out or making any adjustment.

Hydraulic Pumps.—For a press of the above description, two force-pumps made of gun-metal or phosphor-bronze are fixed on a cast-iron tank containing water or oil, one pump being $\frac{7}{8}$ inch to 1 inch diameter, and one $1\frac{1}{2}$ inch or 2 inches diameter, with one valve box placed between the two pumps, provided with a loaded safety valve. Each pump has a strong wrought-iron lever working through guides, the usual plan being to have a casting in the shape of an arch; the centre has a bored boss, through which the top of the plungers work, and one side slotted to form a guide for the lever to work in, and the other for a fulcrum. When worked by hand power, an extra lever, with a socket at the end, is fixed on to the lever of the small size pumps, to give the heavy

pressure. The pumps may be worked either by hand or steam power; in the latter case, the best method is by eccentrics and rods, with pins to disconnect when required, and to throw out of gear.

Such pumps are usually made to give a pressure of from 2 to 3 tons per square inch; if made of gun-metal, they should not be less than $\frac{11}{16}$ inch thick. Phosphor-bronze is a very good metal for pumps, being tough, close, and as a rule both sound and free from blow-holes and other defects; the thickness in this case may be $\frac{5}{8}$ inch.

Hydraulic Cotton Presses.

These presses in most of their details are much the same as the press before described; they require, however, some special arrangements which are noted hereafter. They usually have rams 8 inches to 10 inches diameter, and 5 feet 6 inches to 7 feet stroke; owing to the heavy shocks to which they are subjected, the cylinder and columns and other parts are made very strong.

The cotton is put into a box made of wrought-iron from an upper floor; this box is mounted on four wheels, and has doors at the side near the top to take out the cotton after pressing. When filled, it is run under the press, the ram and table rise and lift up a movable wrought-iron plate at the bottom, inside the press box, and thus press the cotton against the head of the press. When the requisite pressure is given, the top doors are opened, the bale is corded or fastened with iron bands, and is then pushed out. The ram and table then descend, and the box is run out on the rails at the floor level, and a duplicate box, which has been in the meantime filled, is run under the press head, when the same operation takes place.

The size of the bale when put into the press box is 4 feet by 2 feet 6 inches by 6 feet to 7 feet high, according to the description of cotton; after pressing it is about 18 inches thick, and weighs about 400 lbs. The bales are pressed as close as possible to save freight and cost of carriage, as bulk and not dead weight is usually charged for.

Pumps to work presses are usually driven by steam power, and are 1 inch and 2 inches diameter, or in large places a battery of pumps, say four 1 inch in diameter, and four 2 inches in diameter, are set in one tank and are worked either by cams or cranks. To run up

the press-head and take the first squeeze, the 2-inch pumps are used, and by means of trip-gear these are knocked off at a certain pressure, and the 1-inch pumps then finish. Self-acting valve gear shuts off the pressure from the presses when the maximum is obtained.

For India, where the pumps are sometimes worked by a hand capstan, they are arranged in a battery and placed in a circle, commencing with 2½ inches to 2 inches, 1½ inch, 1 inch, and ¾ inch in diameter. As the men walk round with the capstan bars, singing, as they usually do, each pump in rotation, by means of self-acting gear, is thrown out when a certain pressure has been reached. The natives like this method better than working pump levers—it does not appear to fatigue them so much, and the work progresses more rapidly with the former than with the latter plan.

Wood Press Boxes are sometimes used. They are made 3 inches thick at the sides, and are well bound with iron. They are generally mounted on wheels, and have at the top doors to open in the same manner as the boxes made of iron plates. Boxes fixed to the press are not much used, on account of the loss of time in filling them, during which period the press must stand idle. Press boxes made of wood are very suitable in places where the freight and carriage of machinery are heavy, where timber is abundant and intelligent labour can be obtained; there is not much pressure on the sides of the boxes.

In large factories for pressing cotton, there are usually several hydraulic presses; in this case, the pumps are worked by engine power either in batteries, the pumps being 1 inch and 2 inches diameter, or by means of a Hydraulic Accumulator and pumps worked direct by a specially made pumping engine; as a rule the engines are coupled, one of them working direct the 1-inch diameter pump, and the other the 2-inch pump. In large installations, where four engines are worked at the same time, each of the pumps may be graduated in size, so as to commence the pressing with the large pumps, and finish with the smaller ones. In some instances differential accumulators are employed, the valves and connections to carry out such a system are of necessity of a rather elaborate nature, requiring too much space for any detailed description. It may be noted the valves and boxes must be made of hard gun-metal or phosphor-bronze, and must be of the highest quality. Bellhouse's Patent Valves are about the best for the purpose.

It is not intended to enter into much detail as to the design and arrangement of cotton pressing factories, as this must be placed in the hands of professional men, who are well versed in such subjects. It is not a matter that inexperienced people can with advantage satisfactorily deal with.

Linen and Manchester Goods Press.

There are usually employed in a large Manchester warehouse from ten to twelve hydraulic presses; the diameters of the rams vary from 10 to 12 inches, and sometimes 14 inches; the proportion used is generally about six 12 inches, four 10 inches, and two 14 inches; in diameter. All the remarks which follow apply to a large plant of about this power, the author considering the details would be better understood by describing the actual working of such a plant, together with its principal dimensions.

The sizes of the hydraulic presses are—rams, 10 inches, 12 inches, and 14 inches in diameter, and 4 feet 6 inches to 5 feet 6 inches stroke; the tables, 6 feet by 3 feet 6 inches; the columns, 4½ inches diameter; the heads and bases, 3 feet by 7 feet by 20 inches deep at the columns, and about 24 inches at the centre of the ribs; the height from the table to the under side of the head is 6 feet. The cylinders for 7 inches and 8 inches diameter and 4 inches thick; 10 inches diameter, 5 inches thick; 12 inches and 14 inches diameter, 6 inches thick. The working pressure is from 2½ to 2¾ tons per square inch, and in some cases as high as 3 tons. Such pressures, however, are not usually reached in ordinary working.

From three to five presses are usually worked up at *one* time. The speed of the pump shafts is about 65 revolutions per minute; the pressure pipes are wrought-iron and ¾-inch bore. The pressure of the steam in the boilers is varied from 45 lbs. to 60 lbs. per square inch, and when compound or triple expansion engines are used, up to 140 lbs. and above.

The quantity packed by each 12-inch diameter press is from four to six bales per hour; the presses are run up in two minutes, the average rise being about 4 feet; the rest of the time is taken in packing, &c. The time for the 14-inch presses to run up is three minutes. Each press will pack about forty to forty-five bales in ten hours. More work can be done when the engines are more powerful.

The top of the table, and the heads of the presses, have strips of oak fixed on them, leaving spaces through which the iron bands are passed that are used to secure the bales after they have been pressed; the bands are riveted before the pressure is taken off the rams.

Hydraulic Press Pumps.—The pumps for working this installation of hydraulic presses are six in number; they are set on a tank or box, the plungers are 1¼ inch in diameter by 3 inches stroke. The barrels and plungers, with the valve-boxes, are all made of gun-metal. They are worked by a crank or cam shaft of wrought-iron or steel, 3½ inches diameter, having 3½-inch diameter crank pins. The bearings should be at least 4 inches to 4½ inches wide, and made of hard gun-metal, or phosphor-bronze. The crank shaft is carried by an entablature, with the bearings on the *under side* of same; this is for the purpose of taking the thrust on the framing, and *not* on the caps of the bearings. The connecting rods to the plungers have knuckle joints, and are fitted with a steel plate "liner," which is set up by a key as wear takes place; this is for the purpose of taking the thrust off the pins, and prevents knocking and noise. The rods should be 1¾ inch diameter at the ends, and 2¼ inch diameter at the centres, and either made of wrought-iron or steel. The cross-heads of the same, which work on the crank pins, are made of gun-metal, the caps being strongly bolted, and fitted with check nuts and cross-pins.

The pressure pipes are wrought-iron, and ¾-inch bore, and are connected by three 1-inch diameter main pipes to the presses. There are twelve plungers to each pipe.

Each press requires twelve pumps to put on the pressure to 1 ton per square inch; six are then knocked off by self-acting trip gear, and are finished with six to the full pressure, which varies from 50 to 55 cwt. per square inch. As a rule, this pressure is not exceeded, except in very special cases. Safety valves are provided, one to each set, and one to knock off part of each set when the heavy pressure comes on. These valves are fitted with carefully graduated levers, and are marked for the various pressures.

The speed of the pump shafts is from 60 to 65 revolutions per minute; some work as high as 70; it is not however advisable, as it increases the wear and tear of the gear, and, owing to the slip of the water, little is gained to compensate for the higher speed.

All the work must be of the highest class to stand the heavy shocks to which all the parts are subjected.

Engines for Working Pumps of Presses.—For a plant where twelve presses are worked, say, six 12-inch rams, four 10-inch, and two 14 inches in diameter, as above described, it requires six sets of pumps, with six in each battery, equal to a total of thirty-six pumps.

Engines.—One pair coupled with cylinders, 20 inches in diameter, by 36-inch stroke. The speed 50 to 60 revolutions per minute. The pressure of steam from 50 to 60 lbs. per square inch, and about 70 lbs. when the full work is on. Expansion gear is fitted to the engines to cut off the steam according to the amount of work to be done; a governor to regulate the speed should also be provided, as the work varies very much. The steam is usually cut off at ⅝ of the stroke; this, however, depends upon the work. The crank shaft is 9 inches in diameter, and the bearings 12 inches wide; they are made of hard gun-metal or phosphor-bronze, and are supplied with stron caps. One fly-wheel, 13 feet in diameter by 9½ inches wide by 12 inches deep, is common to the two engines. This wheel should be turned on the edges and the rim, and carefully balanced.

Sufficient power is provided in the engines to work the cranes and hoists in the warehouse, either by steam or hydraulic power. For a plant of the size named there would be about four or five cranes and three hoists, each capable of raising 10 to 12 cwt., and probably one or two hydraulic passenger lifts in addition, capable of raising 10 cwt. each.

Boilers.—Two of the Lancashire type, 6 feet 6 inches in diameter, by 24 feet long; and two tubes each, 30 inches diameter. One boiler is sufficient to give the necessary steam; the other is a spare one. The pressure of steam required varies with the work; for three presses at one time, say 50 to 60 lbs. per square inch; and five presses at full pressure of 2½ tons per square inch, say 70 lbs. per square inch. The boilers are usually placed in a separate building, to reduce the risk from fire and so keep down the rates of insurance, which are usually very high in this class of warehouse, owing to the liability to fire and the great value of the goods stored therein.

General Remarks.—When five presses are at work at the same

time, there are usually ten to twelve presses altogether, it being arranged that the extreme pressure can be taken with three or five presses; while the bales are on, the other ones are being finished, and the rams run down, and tables reloaded. Very special arrangements require to be made in the pipes to take off the shocks to which they are subjected. The valves used for putting on the pressure must be of gun-metal, and the type named at p. 73.

Hydraulic Accumulators are also used, as before stated; the pressure in this case is more continuous, and much time can be saved by their use, as the pressure can be stored up by the engines and accumulators when the presses are not in use. This is a case where a differential accumulator can be applied and much power saved, by reducing the water used and the consequent cost of pumping.

Special Pumping Engines for Hydraulic Presses.

Engines and Pumps combined are in some cases used; they are constructed on the following plan. The steam cylinders are placed horizontally, the engines coupled and fitted up in much the same way as those described for hydraulic crane work; the pumps are worked direct from the piston rod, and vary in size and number according to the special requirements. In cases where these direct-acting engines are used, they only pump for the presses, and do not drive other work. The engines may either be high-pressure, non-condensing, or compound.

Another plan is to attach a pair of steam cylinders to the battery of pumps, made as described at p. 75, the tank having a projection cast at each end to form a base plate for the cylinders, which are fixed outside the tank and entablature at either end. A throttle valve in the steam pipe is worked by special levers from the safety valve, to control the speed of the engines to suit the work to be done. The foundation for pumping apparatus of this kind must be made solid and good, and the bed plate well fixed to it, by long holding down bolts and plates.

Vertical High-Pressure (Non-Condensing) or Compound Engines.—These are direct-acting, the pumps being worked directly under each

of the steam cylinders; they are used in places where space will not permit horizontal engines to be employed. This type of engine is the same as those described at p. 14; they are most efficient in action, and especially when made in the three-cylinder form. They are perfectly balanced, the pressure is given in a very regular and steady manner, and quite free from shock or vibration. The engines are fitted with trip-gear to throw the pumps out when a certain pressure has been attained. Mr. E. B. Ellington, M. Inst. C.E., the Author believes, first introduced this form of engine for pumping for hydraulic purposes; the Author had, for several years previous to their introduction, considered it a perfect way of accomplishing such work.

Worthington Pumping Engines.—The advantageous use of this type of engine, when applied to pumping for hydraulic cranes and hoists, &c., has been already alluded to on p. 12. They are equally applicable for pumping under the heavy pressures required for hydraulic presses. They possess many advantages, not only on account of their steady working, but also by their economy in the use of fuel as well as their steadiness in action, and the even and regular manner in which they perform their work. They are made by Messrs. James Simpson & Co., Limited, and cannot be too highly commended.

Hay Pressing.

Hydraulic presses for this purpose are usually made with a rather long stroke; they have to be specially arranged. Presses of different size are used thus: for bundling, the commencing press has a ram 6 inches diameter, by 7 feet 6 inches stroke. Three or four trusses of hay are usually put into the press; they measure about 6 feet high. When pressed one-half, the bundles are taken to a press with a 10-inch diameter ram, of about 3 feet 6 inches stroke, to have the final pressure, which is usually 2½ tons to 3 tons per square inch. The thickness of the bale when finished is usually about 12 inches. The quantity that can be pressed by two men in twelve hours is about 3 tons, and with quick-running presses, 4 to 5 tons. One ton of hay (ship's measurement) varies from 110 to 180 cubic feet; the 10-inch press will bring it to 130 cubic feet; hence, a large saving in freight can be effected.

One set of pumps, 2 inches and 1 inch diameter, will work two presses, and requires an engine of 6 to 8 nominal HP.; the power used depends upon the speed required in pressing. It often pays better to employ larger engines and pumps to turn the work out quicker. When this is done, the 2-inch pumps are used for three-quarters to seven-eighths of the rise of the ram, and a 1-inch or 1¼-inch to complete the pressing. This installation is about the average size for small establishments. The system can be extended and worked in the same manner as described for the linen presses at p. 74, or upon the system named in the next clause.

Mr. E. J. Davis's Patent Plan.

In this system small hydraulic presses are employed with 7-inch to 8-inch rams, by about 4 feet stroke. At the press-head are fixed two wrought-iron rails, on which two cast-iron boxes mounted on wheels run; these press-boxes have a movable wrought-iron bottom, and doors at the top at each side. The boxes are loaded from hoppers placed on an upper floor, and are then run under the press-head; the ram and table rises, carrying up the loose bottom plate, and pressing the hay between it and a top plate which is put into the box after it is filled. When the full pressure is taken, the top doors are opened, and two wrought-iron clips put on each side of the bale, which is thus clipped or held between the two wrought-iron plates. The bales of hay are then taken away on an iron truck to an oven, where they are heated, and the elasticity taken out; after this is accomplished, the iron plates can be removed, and the bales tied with cords. The size of the bale is regulated for a feed of a horse or other animal for a certain time; much economy is effected by this plan, as a large loss usually takes place when the larger bales before described are used, on account of their size, and also being *elastic;* directly the iron bands are cut, the hay expands to nearly its original size, and if all the bale is not wanted for immediate use, it gets scattered or spoilt.

So rapid is this process that the Author has known each press to be run up two hundred times in ten to twelve hours. The pumps in this case are all 2 inches diameter; they are worked by a powerful

engine, which becomes necessary when such a high speed of work is required. The contracts are often taken for the *greatest quantity* that can be shipped in a *certain time*. In such cases no other system can compete with this.

Another advantage of this plan is that oats, beans, bran, &c., can be mixed in the bale, and will keep perfectly sweet for years. The Author, some years since, saw a bale that had been pressed, sent to sea, returned and opened in his presence seven years after it had been pressed. The interior smelled like new hay; and, although it had been much exposed to the atmosphere, was not in any way deteriorated.

When pressing on this rapid plan, the pipes must be well provided with safety and relief valves, to avoid shocks both on the presses and pipes. The engine should be provided with a sensitive governor to shut off the steam when no pressure is being taken from the pipes by any of the presses. An automatic arrangement is also connected with the suction valves of the pumps, to throw them out of gear when a certain pressure has been attained.

This is a case where an Accumulator could be applied with much advantage, on account of the storage of power and the direct control applied to the engine valve to suit the various requirements of the work. It would be advisable to have two Accumulators—one for heavy pressures and one for light; the latter, say, 1 ton to the square inch, and the former 3 tons per square inch, and by two lines of pipes and the necessary valves, the two presses could be used at pleasure.

All the work for this system requires to be very strong, as in working, the shocks to the machinery are of a very heavy character; and unless everything is of the highest class, frequent fractures take place, involving not only heavy expenses for repairs, but much loss of time, which in this kind of work is of very serious moment.

The perfecting of hay-pressing machinery, especially on this plan, is due to Mr. E. J. Davis (the patentee of the process described), who has carried out this class of business not only on the most extensive scale, but with very great success.

Oil Presses.

The presses used for this purpose usually have rams 12 inches diameter and from 12 to 18 inches stroke. The height from the base to the head is 4 feet; there are four $3\frac{3}{4}$-inch diameter collared wrought-iron columns fitted to the head and base as before described. The tables for pressing are four in number; each resting upon steel pins screwed into the columns.

The columns are placed at about 22 by 22 inches centres. The head and base are 12 to 14 inches deep on the outer edge, and at the ribs in the centre 15 to 16 inches deep.

Each of the tables is planed at the top and the bottom, and provided with raised rims all round, with an interior sunk channel to receive the oil. These channels have a fall to one corner, at which point a small copper pipe conducts the oil from each table to a receiver which is placed below.

In the case of linseed, the meal is put into bags and then placed in a stove; when the bags are sufficiently heated they are packed on each press table, and the pressure gradually put on. When the required maximum is obtained, self-acting apparatus throws the pumps out of gear, the bags are removed, and the dry cake taken out.

The quantity turned out is about 40 cwt. of cake and 10 cwt. of oil in eleven or twelve hours; more can be done where a rapid style of pressing is employed; it is not, however, liked so much as the more gradual work, which is considered to extract the oil more thoroughly, and in the result is, in the Author's opinion, the most economical method of working.

The pressure pumps are of the usual character; oil is used in them in lieu of water. The pressure is about 3 tons per square inch, and a total pressure of about 340 tons for a 12-inch ram. For ordinary work this pressure is rarely exceeded.

The column and some parts of the press are made bright; this enables the man to keep them clean, and saves waste of oil.

Presses for Stearine and for like Materials.

These are constructed in much the same manner as described at p. 70. The material to be pressed is placed in bags and piled up to the press-head. The table has a channel for receiving the liquid extracted, and is fitted with a pipe to run off into the receiver below. The rams are 10 inches to 12 inches in diameter, and 6 feet stroke. The presses are usually enclosed in a chamber, to which steam heat is applied, and are closed up until the time when the maximum pressure has been given. The dry substance is then taken out of the bags, and the presses loaded again. In large places there are usually four to six, and sometimes more, presses in the chamber. The pressure varies with the material; it is generally $2\frac{1}{2}$ tons to 3 tons per square inch. The same remarks as to pumps, &c., apply in this case as for the oil presses; the pressure must be put on gradually, and at about the same speed as for oil.

Sugar-Scum Presses.

The presses used for this purpose have rams 10 inches in diameter, by 2 feet 6 inches stroke. The details of the ram, cylinder, &c., are the same as an ordinary press, described at p. 70; the following special construction is added:—

To the head of the press is attached a square piston. The table carries a cast-iron press-box, mounted on four wheels; the thickness of metal is 2 inches at the sides and 3 inches at the bottom. On the inside of this box ribs are cast, and against these ribs four independent copper plates rest; these are drilled with small holes. The sugar or scum to be pressed is placed in canvas bags in the box, which is then run on the table; the ram and table carry up the box against the square piston at top, which presses the goods, the sugar liquor going into the annular space between the box and the copper plates; a cock and pipe allow the contents to be run away into a receiver at the base of the press. The box when lowered is run out on to the rails, and the bags taken out. The distance

between the wheels of the press-box is sufficient to allow the press-table to bear on the *bottom* of the box and not on the *wheels;* the top of the table is grooved for a passage for the wheels to run in.

The *pumps* are usually worked by hand, and are 1 inch and 2 inches in diameter, they are fixed on a tank containing water. The pressure used is 3 tons per square inch. At the time the pressing is required to be done there is plenty of hand-labour available, and as at this period it cannot be otherwise employed, it is more economical to work the pumps by hand than by steam power. This is partly on account of the necessary position of the press with regard to the other plant, and the time of the day most suitable for carrying out this process.

Hop Presses for Breweries.

The spent hops are pressed in hydraulic presses in the same way as above, except that the press-box is made with movable sides, to enable the cake to be readily taken out when pressed. The details of these presses, in other respects, do not materially differ from the sugar-presses, except in some minor details not of sufficient importance to describe.

Hops may also be pressed in movable boxes, on the same plan as cotton, two boxes being used to save time. The following is a description of presses and pumps made by Messrs. Thornewill and Warham, and at work at Messrs. Bass and Co.'s and Messrs. Salt and Co.'s, at Burton-on-Trent. The cylinders are 12 inches in diameter, by 4 feet to 5 feet stroke; the pistons are packed with cup leathers. The pressure pumps are made in two sizes—the large ones to lift the piston quickly after the hops have been pressed, at the same time lifting a series of weights attached to the piston-rod. When the piston is at the top of the cylinder, and the box is filled with hops, a valve is opened, which makes a communication between the top and bottom of the piston; the weights then bring the piston down quickly, and the small pumps are brought into use to obtain the required pressure. The boxes travel on rails; the sides are made slightly tapering, so that the pressed hops can be easily removed. In large breweries several of these presses are used at the same time, the pressure is given by hydraulic pumps worked by engine power.

Improved Hydraulic Hop-Press.—This was designed by the Author; it is constructed in the following manner:—

The cylinder is 10 inches diameter inside, and 4 inches thick; the top part is bored, and fitted with a leather packing in the usual manner. It is cast with a head, or thick flange, which is turned on the under side, and also for a short distance in the barrel. The cylinder rests upon the base-plate, named hereafter, which is bored and faced on the top to receive it. The ram is 9 inches diameter, with a stroke of 3 feet; it is shouldered down to form a pin; the table rests on the ram, bearing against a centre boss; a hole is bored in the centre to form a recess to receive the pin. The top of the table is planed, it is 3 inches thick, and is strengthened by eight ribs on the under side, $1\frac{3}{4}$ inch thick. The base of the press is $9\frac{1}{2}$ inches deep at the outer part, and 10 inches at the centre; it has a hole cast through the centre boss, the upper part of which is bored out.

The head is a counterpart of the table, except that it is cast without any hole in the centre; it is planed on the under side. The columns supporting the head are of steel, $3\frac{1}{2}$ inches diameter, and are provided with double solid collars, which are forged on them; they are turned all over, also the part of the columns between the collars, which are sunk into the recesses in the head and base. The table and head have recesses cast in them, with cover plates, and are fitted in the same way as described at p. 71. At 3 feet 1 inch above the top of the table, two rail bars of steel are fixed to the columns on either side; they are turned up into a curved shape at one end to act as stops; these are for the iron press-boxes to run on.

There are two portable cast-iron boxes, each being provided with four flanged tram-wheels. Each box at the top part is fitted with a hinged door at both ends; this is for the purpose of taking out the cake after the hops have been pressed. At the bottom of the box a loose plate of steel is provided; this rests upon a fillet, which runs all round the sides of the box.

The method of working the press is this: the two movable boxes run on rails; they are placed at a level convenient to fill them from the hop-backs; the spent hops are thrown from the backs into hoppers and shoots, both being made of copper plate; when the first box is

filled it is run on rails, which are in connection with those attached to the press, directly over the table of the ram; the pressure is then put on, and as the ram rises the hops are compressed, and the beer runs out at the holes provided in the sides of the box into proper copper channels and receivers. The top doors are then opened and the dry cake pushed out. The empty box is then run out, and the other box, which has been in the meantime filled, run in, and so no loss of time takes place. The pressure pumps are the same in detail, and are worked by engine-power in much the same manner as described for other purposes. In large breweries several presses are required; they are arranged at levels, and in positions to suit the different hop-backs.

The Author's system can be applied for pressing other materials.

Drugs and Essence Presses.

For drugs, the ordinary hydraulic press is used; and for essences, a press with ram 6 inches in diameter by 12 to 18 inches stroke; the press-box is made of gun-metal, and is tinned inside. In addition to this, the table has a sunk channel all round it, to prevent any loss of the liquid expressed. Where the drugs are delicate, the top of the table is faced with gun-metal and is also tinned. One pump, 1 inch in diameter, is fixed on a circular tank containing water or oil; it is worked by a hand lever. The pressure is about 1 ton to 1½ ton per square inch.

The general details of the press are much the same as before described, except that for small presses two columns may be used in lieu of four; they are usually turned, and made bright.

Hat Making.

Hydraulic presses are used for making low-crowned felt hats; it is a very ingenious application of the power. The hat is placed in an iron mould, which is carefully filed and got up to the exact shape required. A top plunger shape, also filed and got up to a perfect shape, is then brought down to the rim of the hat, leaving a space in which is an india-rubber bag; the hydraulic pressure is let *into*

the bag, and an even pressure is thus given to the material. When the hat comes out of the press the shape is perfect.

An accumulator, with a ram 6 inches in diameter and 4 feet stroke, will work ten of these presses. The pressure required is 150 to 160 lbs. per square inch. The pumps to give the pressure can be worked by the general engine; the distance from the same to the presses is not a matter of much moment. In addition to the accumulator, it is advisable to have a good-sized air vessel, to ensure steady and even pressure. To keep this properly charged with air, see the former remarks on this subject, under the head of Hydraulic Lifts. This same kind of apparatus is applied in various other cases, the details of which vary according to special circumstances.

General Remarks on Hydraulic Pressing Machinery.

Cylinders and Rams.—Where very heavy pressure is to be employed, cast-steel cylinders are now adopted with much advantage; they are, as a rule, absolutely sound, and not porous like cast iron. They are of necessity rather costly, but where the work is heavy, and taking into account the cost of an occasional fracture with a cast-iron cylinder, it pays to use steel. Messrs. Hadfield & Co., of Sheffield, have given much attention to this matter, and have been most successful in the production of sound steel cylinders of 10 inches diameter and up to 8 feet long. When the first edition of this book was published, only cylinders of short length could be successfully produced. The Author is glad to mention this work done by Messrs. Hadfield and Co., as it has proved a great boon to makers of hydraulic machinery during the last few years.

In casting Cylinders and Rams the metal should always be run vertically, and great care taken to get off the air and gases, to ensure a solid and good casting. Only a selected description of metal should be used, the moulds carefully dried, and the temperature to run the metal should have particular care. It is necessary to leave the castings in the sand for some time to anneal them, and uncover them gradually. One great cause of unsound castings is leaving the mixture of metal, and the proper time to run it, to

ignorant workmen, when it really requires the most skilful and careful attention from the chief of a firm or their manager. In the Author's opinion, most of the unsound castings made may be traced to this cause.

Press Pumps.—The best metal to make them of is bell-metal or phosphor bronze; the various parts of the casting should be carefully proportioned, to prevent unequal contraction when cooling in the sand; all castings should be carefully annealed. Much care is required in fitting the cup leathers, as well as seeing that the recesses to receive them are the proper shape and dimensions.

Pressure Pipes.—The best are Perkin's high-pressure wrought-iron pipes; the threads must all be cut in a lathe, and all the various junctions and caps, &c., must be of hard, close gun-metal, most carefully fitted. At the junctions with the valve boxes and the hydraulic cylinder, discs of leather must be used to make the joints.

Water Tanks for Pumps.—These must be kept clean and perfectly free from dirt and grit; they should be closely covered, frequently emptied, cleaned out, and the water renewed. Oil is preferable to water for use when the goods to be pressed will not be injured if a small leakage takes place.

Valves for Hydraulic Pressure must be made of the best materials and workmanship, and should always be in solid gun-metal. There are several patented, most of which answer the purpose well. It must be borne in mind that this is a very important matter, as, if leakage takes place, there is much loss of power, especially at the higher pressures, and where there are many presses, involving many joints and junctions in the pipes which carry the pressure.

Safety Valves and Relief Valves.—Great care must be taken to ensure instant relief to the pipes in case of any undue sudden pressure, and that the suction valves of the pumps are thrown out of action when the maximum pressure is obtained. Safety valves should be placed at various points on the pressure pipes, especially where they turn or run in a different direction, to ensure that the extra pressure in the pipes at any point finds relief as near the same as possible, added to which, if one safety valve should stick, one of the others is sure to act. These safety valves should be made with knife-edges, working on flat faces; or, if the valve is made conical,

the seat should be narrow. When the valves and seats are made as above, they are very sensitive, and more likely to give instant relief to the pipes in case of any unusual or violent shock.

Leathers.—The ∩ shape for the rams, and ∩ (hat) shape for the pressure pumps should be made of the best oil-dressed leather, cut out of the *middle* of the back of the hide, and dressed down to an even thickness before commencing the pressing. The leathers are pressed in cast-iron moulds; the pressure should be gradually put on, and the leathers left several days in the presses to harden. Inferior leather is useless for the purpose, and will not stand any wear. When they are well made, of the best materials, and carefully put in, they last a long time—in hard-worked presses two years and upwards, and those used less often for several years. If, however, they are put in by ignorant people, and dirty water is used in the presses, they do not last long; this is very false economy, shown not only in the destruction of the leather, but in the wear of the pumps and values.

Steam Power Pumps, &c.—The engine power should be ample; variable expansion gear should be provided to accommodate the varying work that may be required. In all cases double cylinder or coupled engines are necessary, as they are more easily controlled, and can be started at any point of the stroke. Where the presses are worked by an accumulator, the same controlling apparatus is used as described for the cranes, except that more pumps are attached to the engines, to suit the heavy and light pressures.

Foundations.—As before stated, at p. 71, the cylinders should hang *free* in the pit; the base of presses should rest on timber, on a brickwork or concrete foundation. On no account should the cylinder touch the sides or the bottom of the foundation, or be grouted in with liquid cement.

CHAPTER II.

HYDRAULIC WORKSHOP MACHINERY.

To a very limited extent the application of water power to punching and other machines dates back some years. To Mr. R. H. Tweddell must, however, be awarded the merit of first bringing the system into practical use upon a large scale, for riveting in the first place, and later on by the introduction of his patent machinery to hydraulic machine tools generally. This application of hydraulic pressure, however, to portable machines, that is to say, those which can be taken to the work, instead of having to bring the work to the machines, constitutes the most original and interesting branch of Mr. Tweddell's system, yet the first successful introduction was due, so far as riveting machines are concerned—

First. To the employment of a very high pressure of water, namely, from 1500 to 2000 lbs. per square inch, which reduces the sizes of all motive parts, and, consequently, the weights—some of these machines, although exerting a pressure of many tons, only weighing a few pounds.

Second. To the adoption, in certain cases, of a form of Accumulator which, so far as the stationary riveting machines especially are concerned, acts not only as a reservoir, but also as a means of greatly intensifying (for the moment) the above high static pressure; and also allows the full static pressure to be maintained on the rivet-head as long as may be desired. It was to this general combination that the success of *hydraulic* riveting, on its first introduction, was due.

Many of the largest boiler, girder, ship yards, and wagon building companies have been fitted up upon this system. The Author has seen it in action at several large places, and considers it most perfect machinery of its class, and far superior to a steam

power plant. The working is more economical than any other system, and the power better under control, while the freedom from vibration, and the saving in costly foundations, especially recommend it for practical use.

In this system on a large scale, no shafting or gearing is required to drive the machines; the power is obtained by pumping water into an Accumulator, somewhat similar to those used for hydraulic cranes. The pressure from this is conveyed to the various machines by pipes in the usual way, the power being stored up in the Accumulator, ready at any moment for application. Machinery of this class is inexpensive to keep in repair—the wear and tear, owing to its entire cessation from movement when not doing useful work, being slight, much less wear takes place, and consequently the cost for maintenance is much reduced.

All of the machines being self-contained, and many of them portable, they can be used in any part of the works, and their distance from the Accumulator is not of much consequence. The apparatus is thus very suitable for outdoor work, such as erecting heavy bridges, since all the apparatus can be made portable. A great saving of time and cost is effected in such cases, the work being infinitely better done than by the best hand work, it being well known that, in erecting work outside, hand work is often done under very great disadvantages.

Accumulator.

The pressure for riveting machines is in some cases obtained by pumping water into a Differential Accumulator; this may either be done by a pumping engine similar to those described at p. 10 for hydraulic cranes, or by a set of pressure pumps driven by a strap from the shop shafting. This latter plan will often be the most convenient where a stationary engine is already in use for *other purposes* of the works.

The pressure used is 1500 lbs. per square inch in this country, but in all machines used on Mr. Tweddell's system in America, the pressure employed is 2000 lbs. per square inch.

Drawing No. 44 shows an elevation of a differential accumulator, half in section. The water is pumped in at A, and passes into the moving cylinder, B, by the holes, C. The cylinder then rises, owing to the pressure exerted on the shoulder formed by the difference of diameters of the spindle, D D, at C. Any required pressure is obtained according to the number of weight rings, W W, put on. The water passes to the machines through the outlet, E. Suitable valves are fixed, not only to prevent accidents from too much water being pumped in, but also to automatically stop the pumps, whether driven by belting or separate engines, when the accumulator is filled. Other ordinary forms of accumulators, similar to those used for cranes (see p. [illegible]), can be used when a complete shop is fitted up on the hydraulic system, or for working flanging machinery and other purposes.

There is little reason to doubt, from the results obtained in practice, that, in a complete hydraulic workshop, only about one-third to a quarter of the boiler power would be required as compared with that necessary where ordinary steam or geared machinery is used, and even better results when compared with the system of separate steam cylinders attached to each machine. The loss of useful effect between the pressure pumps and the accumulator has been shown by experiment not to exceed 3¼ to 4¾ per cent. The loss by friction in the accumulator is only 1 per cent., and taking the friction at the machines themselves, which does not exceed 1 per cent. also, we have only 2 per cent. total loss from friction in the machines.

The Power absorbed by shafting has been shown by experiments in a length of 1200 feet of, say, 2¾ inches in diameter, *with all the straps off*, to be about one horse-power indicated for every 100 feet of shafting. If to this is added the friction of the belts and the gearing of the various machines, it will be seen the loss of power is much greater by shafting and gearing than in the direct application of hydraulic power transmitted from a distance through mains. Another interesting fact is that, in consequence of the motion of the hydraulic machine being least when giving off the greatest pressure, the speed of the water in the main is at its slowest, and therefore the friction is least.

In addition to the above considerations, the hydraulic system must be credited with all the economy obtained by the saving it effects in expensive roofs and walls, required *not* so much for shelter as for carrying shafting and pulleys; the absence of all foundations; and also the saving in head room, and the consequent greater facility of working cranes and travellers, owing to clear headway. There is again a great saving in shop floor room, and in boiler and ship yards where much riveting is done, the portable riveters, by enabling the work to be quickly turned out, make a small ground area as productive as a large one not so fitted.

Riveting Machines, Stationary.

In these machines the closing pressure upon the rivets is capable of adjustment, according to the requirements of the work. The pressure brought to bear on the rivet combines the effect of a blow and also a steady squeeze or pressure, which pressure can be retained as long as desired. This property is also taken advantage of to lay the plates together before riveting, thus saving much heating and risk of burning the plates. From ten to fifteen rivets per minute can be closed in boiler work, and for girder work a considerably greater speed can be obtained.

The force exerted varies from 5 to 150 tons closing pressure upon the rivet-heads. In practice it is found that 40 tons can do any work up to 1¼-inch rivets in 1-inch plates. Too high pressures are very apt to injure the plates.

One of the latest forms of these machines is shown at Drawing No. 45. As will be seen, the cupping die is flush with the top of the cylinder, thus enabling the rivets in flanges and angle irons on flat surfaces, and the throats of locomotive fire boxes to be readily reached. In this case the cylinder and gear are all *above ground*, and the action is *direct*—a great point, if it can be managed. As a rule, the hob, or dolly, should be of steel or wrought iron, to allow of small flues being got over it for riveting. The stroke of the dies is such that if the rivet is too short, the full pressure is given to close it; if too long, no harm comes to the machine, and different

numbers of thicknesses of plate can also be riveted without any special adjustment.

Drawing No. 46 shows a very powerful class of stationary riveting machine. It is similar in general design to that shown on Drawing No. 45. As the power of these machines has been so greatly increased, some means of lessening the consumption of water has become a matter of necessity. This is effected by means of a small auxiliary ram, worked by its own valve. This small ram is just powerful enough to move the main rams until they commence to close the plates and the rivets; until this occurs the cylinders are filled by low-pressure water, drawn from the overhead tank, A. When they can no longer be pushed forward by the auxiliary ram the accumulator pressure is admitted in the usual way. The saving in high-pressure water is from 60 to 70 per cent. These large machines are also fitted with a patent plate-closing arrangement, that is to say, an additional ram is provided, carrying a special tool at B; this slides over the cupping die, and closes the plates before the rivet itself is formed and headed in the usual way.

The value of this addition is theoretically very important. But while many makers have followed this system as first introduced by Mr. Tweddell, some engineers question whether it does any better work than that done by his older machines, in which the closing of the plates was done by putting into the machine a flat-headed tool, and first running this round the seams, and by tightening up the bolts before riveting was commenced.

Portable Riveting Machines.

These machines will close, say, 300 rivets from 1 inch to 1¼ inch in diameter per hour; they are very useful in the workshop, and can either be suspended from special cranes or can be hung temporarily from ordinary cranes over the work to be riveted.

Drawing No. 47 shows the type of machine first patented by Mr. Tweddell, but with several recent additions in details; it will be seen that it has two levers. The rivet is closed by causing the

cupping dies attached to the levers to be brought together. Either end of the lever may be used for riveting, the other end, of course, acting as the fulcrum. In this way *two* gaps are available—one, a short one, capable of closing large rivets; the other doing proportionately smaller rivets at a greater gap. The pressure water is brought through the curved tube by which the machine is suspended. This combination of suspending gear and pipe is used in several forms; it simplifies the tackle about the machine, and allows it to assume various positions without breaking any joints. It may here be observed that Mr. Tweddell has frequently acknowledged the valuable assistance he has received in designing machines on his system (especially for riveting purposes) from Mr. James Platt and Mr. John Fielding, and indeed many of the later machines about to be described are jointly patented.

Drawing 48 shows a portable riveter of the lever type. This possesses several advantages over the direct-acting type shown on Drawing No. 50, since, in the former, the working cylinder is kept away from the cupping dies; this, of course, permits the cupping dies to close rivets which are inaccessible to the direct-acting cylinder machine. But on the other hand the direct-acting type was always more rigid, as there were no levers or gudgeons to work loose. This defect was completely overcome by the use of a curved ram, working in a cylinder of the same form as shown on the machines, Drawing No. 48, the radius of ram and cylinder being struck from the centre gudgeon, B. This drawing also shows a form of compound hanger, which is applied to all classes of portable riveters, when a great variety of positions is necessary to close rivets in many different plates.

Work done.—In bridge work, about 2000 rivets per day can be put in on straight girders; as many as 5000 rivets have, however, been put in by one machine in ten hours.

In wagon work, riveting the frames of wagon bodies at works in Scotland, 2100 rivets have been closed per day by one portable riveter.

Drawing No. 49 shows a machine designed for riveting locomotive fire-hole doors, angle-iron rings for marine and land boiler

fronts, furnace rings and lattice girders. The riveter proper, R, is connected to a compound hanger B and B^1, and being placed inside a locomotive fire box, the man has nothing to do, when the fire hole is circular, but turn it round on the gudgeon, C, thus closing the rivets in its circumference consecutively, and, if oval or square, it can do them also with a very slight adjustment of the lifting tackle. This machine, being direct-acting, can be made very powerful for small gaps, and can close large rivets.

One of Mr. Webb's angular fire hole door rings is shown in dotted lines, with the riveter also dotted, shown as it appears when adjusted to rivet this class of work.

In locomotive shops, as many as ten rivets per minute have been put in foundation rings by these portable riveters, the rivets being $\frac{7}{8}$ inch in diameter and through a total thickness of copper and steel of $3\frac{3}{8}$ inches.

Drawing No. 50 shows another form of portable riveter, suitable for boiler flues, bridge work, girders, tender tanks, and work where a long gap is desirable. Most of these machines range from 3 feet to 8 feet, and are specially designed for lightness; otherwise their principle of working is the same as older types of fixed riveters.

These machines can be suspended from overhead travellers, or a fixed crane, as shown at Drawing No. 51. The suspending gear is so arranged that they can hang with their levers either in a vertical (as illustrated) or a horizontal position.

The cupping dies of these machines can also, when necessary, be made flush with the top of the cylinder (see Drawing No. 51, showing one suspended to a crane), in which case (as shown at Drawing No. 50), the cupping dies, A B, can rivet angles, &c., on flat surfaces, without the outer radius of the cylinder, C, coming in the way.

It is true that in Mr. Tweddell's first patent (see Drawing No. 47), the cylinder is out of the way also, but when the gaps come to be considerable, this form of machine, owing to its having two powers (and in consequence two gaps), becomes too bulky, and without sufficient compensating advantages. It is, then, better to dispense with this double action, and, by adopting another order of levers, sacrifice the use of the other end of the levers for riveting, and place the cylinder there (see Drawing No. 48).

There are many other different kinds of riveting machines made under Mr. Tweddell's system, but it is unnecessary to particularize them, their number and variety only proving the applicability of hydraulic pressure to this class of machine tools. The application of portable machines, however, would be comparatively limited were there not also sufficient means of taking or applying the machines to their work, so as to do away with manual labour in this work also. For this purpose hydraulic power is, perhaps, in its best field, and by the use of hydraulic lifts (which not only do the lifting and lowering but also serve to conduct the pressure to the tool), two purposes are served—first, the size, and consequently the capacity for work of the machine, is no longer limited by the weight which men can handle, and all pipes hanging about in the way are avoided.

Fixed Hydraulic Crane and Lift.

Drawing No. 51 shows one of the numerous types of these cranes. A vertical lift of from 4 feet to 6 feet is obtained by means of the hydraulic lift, A, placed between the riveter and the travelling carriage, B. The carriage travels the whole length of the jib, C, and the riveting machine, D, can be racked in and out, without disconnecting the pipe joints. A crane fixed in the wall, and having 28-feet rake, can rivet any work placed within an area of 1200 square feet.

Very large and heavy machines can, on this plan, be used as portable tools, since all the raising and lowering is done by hydraulic power. In many cases these lifts are simply suspended from the end of an ordinary travelling crane chain, and in other cases hydraulic travellers are used, each case having to be treated on its own merits.

When no lifts are used, small copper pipes are employed to conduct the pressure water. These pipes are coiled in a spiral form. A spring-like action is thus secured, which allows the riveter to vary its position within considerable limits; and in practice, the copper piping is found to answer perfectly, and it is not subject to the damage inseparable from the use of india-rubber hose.

In many cases, however, the work to be riveted is spread over so large an area that a travelling crane is necessary, which is hereafter described.

Travelling Hydraulic Crane and Lift.

Drawing No. 52 shows this crane; it can travel from 20 feet to 30 feet along the ground or the shop floor without disconnecting any pipes, and, with a jib of 28-feet rake, a floor area of 4000 square feet is covered. The great advantage of this plan is that the work on girders and similar work can be going on in different stages on either side of the rail on which the crane runs, erecting and plating on the one side, and riveting on the other; or the crane can be used for plating and erecting first, and riveting afterwards. Pressure mains are led from the Accumulator to the lifting cylinder on the jib and to the riveter. The jib in Drawing No. 52 is free to revolve all round. A hydraulic chain lift, attached to the travelling crane, serves to raise and lower any weight up to 1 or 2 tons. Two similar cranes, but with a different form of framework, are often placed at the head of a ship-building slip, and all the floors and frames riveted up as they pass under on their way down the keel, across which they are laid for riveting before being up-ended. As soon as the ship is done, the cranes are moved to the next berth, or in some cases placed inside the hold for riveting up the floors, &c. Ship riveting, so far as the shell work is concerned, is a problem yet to be satisfactorily solved; but so far back as 1872, in a paper read before the Institution of Mechanical Engineers, at Liverpool, Mr. Tweddell described his mode of riveting ships' frames, keels, &c., which is now practically carried out, and used by all leading shipbuilders. The crane shown in Drawing No. 52 is used in locomotive works, and arranged to allow of the small locomotives used to transport material from one part of the works to another to pass under the travelling crane which carries the riveter.

Portable Riveting Plant (Drawing No. 53).

The characteristic of this arrangement is that not only is the riveting machine carried on a crane, but the motive power for driving it also, and since the waste heat from the rivet-heating furnaces nearly suffices to drive the pumps, it is evident that, so

long as the rivets have to be heated, nothing more economical as to cost of working can well be devised.

The object of this design is to meet cases in which the bridge is to be erected on sites where skilled labour is often difficult to obtain, and much of the riveting work is very heavy. This plant has not only been considerably adopted abroad, but also used in England. The first bridge, indeed, ever riveted by hydraulic machines was thus done by Mr. Tweddell in London, in 1872, on the Great Eastern Railway Extension Works at Bishopsgate Street. But little description of Drawing No. 53 is required. All the lifting, racking, travelling, and other movements can, if desired, be done by power from the engines which drive the pumps. The accumulator spindle is utilized to serve as a crane post, and all the gear turns round this. The crane jib is made a great height, on account of doing the deepest girders.

Small hydraulic punching, shearing, straightening, and bending machines can readily be attached to the bed plate, and are very useful; of course the pressure is available to work other riveters, which, for the time being, may be suspended by ordinary tackle on other parts of the work.

Hydraulic Punching and Shearing Machines.

Drawing No. 54 shows a hydraulic punching, shearing, and angle-cutting machine on Mr. Tweddell's system. The largest sizes hitherto constructed can punch $1\frac{1}{4}$-inch holes in $1\frac{1}{4}$-inch plates, and shear plates of $1\frac{1}{4}$ inch thick at a distance of 5 feet from the edge of the plates. The advantages of this system come out more prominently as the work to be done becomes heavier. When the plates are in the proper position to be punched, the workman admits the pressure; this is entirely under his control, and the punch cannot descend until he is ready.

The pressure cannot exceed the load upon the accumulator; and hence it is immaterial whether there is too heavy a piece of work put in or not, as the machine cannot be strained.

The machine works silently; there is no noise or vibration, and on this account foundations are unnecessary.

As each cylinder with the tool holder attached is independent, an accident to one of them does not cripple the whole machine, as is the case when gearing is used; and as each tool works independently of the other, the man has not to wait until the stroke of the tool at the other end of the machine is completed. Each part of the machine is self-contained, and, if desired, it can be taken into three parts and placed separately about the yard, or taken to where it is temporarily wanted, and then connected to the mains. The facility for putting on special tools or stamps is also very considerable; and the shear blades are so attached that they can very readily be altered to any angle by moving the blocks which hold them.

The valve gear is arranged so that the amount of water used is proportionate to the thickness of the plate punched. The angle and bar cutter is shown placed between the punch and the shears, but of course the combinations are practically endless. A great incidental advantage is the clear headway obtainable for cranes, owing to the absence of belting or shafting.

Amongst the other different applications may be mentioned the following machines.

Chain Cable Shearing Machine (Drawing No. 55).

In this modification of the hydraulic shears just described, the general principle is, of course, the same. The cable, although cut in one stroke, is, by stepping the knife, A, really cut in two efforts, thus allowing the area of the cylinder to be halved, although, of course, doubling the stroke. The same amount of water is therefore used, but considerable structural advantages are secured. The machine is a double-ended one, and chain cables from ½ inch up to 3½ inches in diameter can be cut without requiring any alteration in the knives.

As in all Mr. Tweddell's machines, the return motion is automatic, and effected by hydraulic pressure. These machines are in use in most of the principal public chain-testing establishments in this country, and are worked both by pumps direct and also with accumulators.

RAIL SHEARS (Drawing No. 56).

This illustrates another mode of applying hydraulic power by the use of a steam accumulator. This device has been used for many years, the novelty in the present machine consisting chiefly in the use of an automatic cut-off gear, which it is not necessary to describe in detail here. The principle of the apparatus is this: A large steam piston in the cylinder, A, and subject to pressure of steam from a boiler, and having a considerable length of stroke, imparts a proportionately intense pressure per square inch on the fluid in the smaller cylinder, B, placed above it. The water in cylinder B being thus under great pressure, is conveyed through a pipe, C, to the hydraulic cylinder D, with a ram carrying the rail shears, E. The ram in cylinder D having only a very short stroke and a considerable diameter, the power stored up in the cylinder B is applied to great advantage.

Without the intervention of this apparatus, it is clear that with the same steam power an impracticable size of shearing ram would be necessary, as the space through which the tool travels is so limited.

The apparatus illustrated in Drawing No. 56 is intended to be carried in parts on railway trucks from one depôt to another, utilizing the steam from the boiler of the locomotive which draws it. All old rails there accumulated are cut up to scrap, and the apparatus then moves on to the next station, and works off the old rails there.

HYDRAULIC MULTIPLE PUNCH (Drawing No. 57).

This is a very compact arrangement for punching a large number of holes simultaneously. The machine has a punch bar and die holder, each about 6 feet long; the punch bar is moved by the hydraulic ram, A, acting through a parallel motion composed of rollers working in inclined planes. The return stroke is effected by means of a ram acting through the crosshead, B. It is obvious that shear blades can be substituted for the punches. Hydraulic-pressure

tools are from the steadiness of their action especially suited for this class of machine. Owing to the entire absence of gearing the tool occupies very little floor space, and thus leaves room to manipulate the work to be done. The punches are, of course, stepped—that is to say some are longer than others; this enables the work to be done with a smaller diameter of ram, but, of course, with a larger stroke. In some cases hydraulic cranes are placed on the machine, worked by a valve placed alongside that which works the punching press; one man, therefore, does all the work connected with working the press and lift.

Stamping, Corrugating, and Forging Presses (Drawing No. 58).

This press is used for corrugating sheet iron or steel plates for roof work, and also as a stamping machine for fence pillars, footsteps, &c. It will corrugate plates 12 feet wide by $\frac{1}{16}$ inch to $\frac{1}{4}$ inch thick, and could even take in larger sizes. This class of machine only shows one of the many applications of hydraulic power. The well-known "Mallet" buckled plates have for many years been so manufactured, and similar machines have been made for stamping plough breasts and shares, and in fact shaping and moulding all descriptions of work. It is impossible to illustrate all these various applications, more especially as very often the chief points of interest centre in the ingenuity displayed in the construction of the necessary moulds and blocks. Disc railway wheels, threshing machine drumheads, are also so stamped. Carried a step further, these machines develop into forging presses, and very good work has already been done in this way.

Forging Press (Drawing No. 59).

This press is a recent design for a machine of this class, the chief points to notice being the arrangement of the main cylinders, these being all placed below the ground level; these are three in number, A A and B, thus three different powers can be exerted, and the consumption of water thereby proportioned to the work to be done.

The anvil block, F, is in the main framing, and the trip, or moving anvil, C, is carried on a moving crosshead, D. The pressure is applied to the work by the main rams acting on the tension bolts, E E, which move the crosshead to and from the work. This entirely novel arrangement avoids all overhead gear and vibration, besides leaving clear head-room for the cranes, &c., required to manipulate the forgings. From an economical point of view the three rams enable the work to be done with, in many cases, one-third of the power required when a single cylinder press is used. The movable anvil is under perfect control, and can take a long or short stroke as desired. It is now generally concluded that a steady pressure (such as that given by hydraulic power) acts much more efficiently to a far greater distance inwards than when a blow only is given. These large presses are worked in some instances direct from an accumulator; this is the best plan—of course in such cases provision is made to allow of the cylinder being filled with low-pressure water when the actual total working power is not being employed. The maximum pressure of water per square inch varies from 2 to 3 tons.

Bending and Straightening Machines.

This is another useful class of machine, and although hydraulic power obtained by means of a hand pump has often been used for this work, the machine shown in Drawing No. 60 possesses some novel features in addition to the quickness of working, due to the use of an Accumulator. The length of stroke of the ram, A, is regulated by means of tappet gear, B, and of course by the same means it can be kept uniform for any work where much repetition is required. The outer abutment blocks, C C, it will be seen, are moved towards and from each other by means of a right and left handed screw, D D, thus keeping their positions relative to the moving block, E, on the ram, A, correct, and capable of adjustment to the greatest nicety. By means of a coupling on the centre of screw at H, each side may, if required, be worked independently. No breakages can occur should too heavy a beam be put in, as the pressure due to the accumulator cannot be exceeded, and as these machines are made to exert a pressure varying from 10 to

100 tons, all classes of work from small angles 4½ inches by 4½ inches by 1¾ inch up to I section of the largest sizes rolled, can be bent or straightened.

Flanging Machine.

Drawing No. 61 shows a type of machine capable of flanging plates of all forms. These presses have been made powerful enough to flange steel plates 1¼ inch thick and 12 feet in diameter. The mode of working is as follows. The ram, A, in the main cylinder, A_2, carries a table, B, on which is supported a hollow matrix, C, made of suitable form to pass over a fixed die or block, D, but leaving enough space between their respective surfaces all round to enable the plate, E E, to be moulded. The action is a somewhat peculiar one, since the matrix, C C, passes beyond the block, D, leaving the plate on the latter. This being left still hot, easily falls off by its own weight, and is removed. There is, however, a very important matter to be attended to, namely, holding the plate firmly to the upper block, while the matrix, C C, is passing over it.

The four small cylinders, H H, carry a flat table, I I. This table being held firmly against the top block, D, with the plate between them, prevents any buckling of the latter.

Very great speed is obtained in working by these presses; in some agricultural workshops as many as 100 smoke box end plates have been flanged in nine hours, and a large plate for the back end of a marine boiler combustion chamber in one minute and a half from the time of opening the furnace door to the plate being levelled and finished.

Hydraulic Flanging Press (Progressive System).

The quality of the work done by the class of press illustrated on Drawing No. 62 is unexceptionable, but the cost of working, when the plates are large, is very great on account of the expensive dies and blocks necessary; and this is especially so in marine boiler work, when the diameters of the plates are very large and the flanges

of great depth, in some cases being 11 inches to 12 inches deep, and $1\frac{9}{16}$ inch thick. These considerations and the great variety in shapes and dimensions of marine boilers, put the old form of press out of the question for private firms, who would perhaps have to make a complete set of dies weighing many tons, and then only be able to utilize them for, say, six or eight boilers. The arrangement of flanger shown on Drawing No. 62, obviates all these difficulties, reducing the cost of dies to a sum practically inappreciable. There are three hydraulic cylinders necessary.

In Fig. 1.—The centering pin, P, having been adjusted to give the right diameter to the end plate, Q, the vice ram, A, is brought down on to the small segmental anvil, N. Then the ram, B, descends, and by means of a suitable block turns over the plate; this process is repeated until about 8 to 9 feet of flange is done. The ram, B, is then drawn up out of the way, and the horizontal ram, C, carrying a straightener or hammer at the end, moves forward and squares up the flange on the block. The hydraulic crane shown above the flanger is a very important part of the plant, as it greatly facilitates the handling of these large plates in and out of the furnaces, and is also useful for storing the different dies and blocks.

Fig. 2.—Shows the two rams, A and B, connected together by a suitable block, for doing the furnace mouths in one operation.

Fig. 3.—Shows the same for dishing dome ends. In this case a fourth cylinder, D, is often found useful to prevent buckling. It will be seen that Figs. 2 and 3 work practically on the same principle as the press shown on Drawing No. 61.

Fig. 4.—Shows another application of the same press for flanging Adamson's rings. In fact, the press can, it is evident, be used for a great number of purposes. While the press is doing the work shown on Fig. 1, it is perhaps one of the most human looking pieces of mechanism yet invented, as it almost exactly imitates in its action flanging by hand.

All the applications of hydraulic power referred to in this article have been confined to machines having a reciprocating action, and, as a rule, exerting a great pressure through a small distance; but there is little reason to doubt that, from the very favourable results already obtained at Toulon Dockyard and elsewhere, there is an

ample margin to allow of even rotary and other motions being economically performed by hydraulic pressure.

The simplicity and efficiency of three-cylinder hydraulic engines have already caused them to be thus used for capstans in large iron working shops; and there is probably a large field for the use of such machines in connection with bringing heavy work to machine tools. Mr. Tweddell has suggested their use for working the lifts for his fixed riveting machines, and in some cases to use them for driving heavy rolls or lathes, and has applied them for working extensions to drilling machinery in places otherwise impossible of access.*

In the first edition of this book, the Author said he could not too highly recommend this system to the consideration of manufacturers, as the most efficient and economical plant for the purposes named therein. He considered a wide field was open for the application of the system, and he did not doubt that, in a short time, no well-arranged iron-working establishment would be considered complete without such machinery. The above remarks were made in 1881, now eleven years ago; and have been more than confirmed, as this system of machinery is now looked upon as an absolute necessity in any establishment for which it is suitable, and where it is intended to carry out the highest class of work. The Author considers this class of machinery is one of the most ingenious and useful applications of hydraulic power; and Mr. R. H. Tweddell is to be congratulated upon his success in a field he has practically made his own.

* See Appendix, p. 191.

PART III.

STEAM LIFTING MACHINERY.

CHAPTER I.

STEAM CRANES.

The application of steam power to cranes and other lifting apparatus does not date more than about forty years ago; and for wharf and other cranes, did not come into extended use until within the last thirty years; they are now very generally adopted, and in some places are more suitable for use than hydraulic cranes.

Steam power is applicable to wharf and warehouse cranes and jibs, as well as for portable cranes of all descriptions used in factories or railways, and for contractors' and other outdoor purposes. There has been much discussion as to the proportionate economy in working between steam and hydraulic power. The first cost of installation is much less for steam than hydraulic power. As to the latter system, it possesses the advantage that it can be employed in places where no boiler would be permitted; and in districts where pressure can be obtained from the hydraulic power companies' mains (taking into account their moderate charges) it seems probable the cost of working under these circumstances may not be more than steam power. Where boiler power is required for other purposes in a large establishment, steam power commends itself by the facility and convenience with which it can be carried to the machine where the power is required. The distance from the boilers up to 600 or 700 feet, or even more, is not material, provided proper arrangements are made to protect the pipes, and to carry away the condensed water.

The application of steam power for various lifting purposes will now be treated in detail in their respective sections, in which will also be set forth the advantages attending the system. Examples will be selected, giving the best modern practice. The Author would here caution those who decide upon such apparatus only to adopt machines of the highest class, and made by manufacturers of good repute; it would be difficult to name any class of machinery where the competition between various firms has been more reckless. It is, therefore, necessary for those who are called upon to select, not to be induced to try machines because they are cheap, but to remember the lowest priced work seldom proves cheap or satisfactory in the end, and that for lifting weights, when an accident may cause injury or loss of life, too great care cannot be used. In too many instances when accidents take place, they are caused by indifferent and faulty work in the machines.

Steam Wharf Cranes (Drawing No. 63).

Steam power cranes are very suitable for wharf purposes when several cranes are required. One or more boilers placed in a central boiler house can work the whole; the capacity of the boiler should be ample for the purpose of meeting any sudden demand; when no work is being done by the cranes, the boilers are reservoirs of steam until they are again required. The Author believes, some years ago, he was one of the first in London to carry steam long distances, and to prove, when the work is properly designed and well executed, that very little loss takes place from condensation in the pipes. This matter will be treated more fully hereafter.

Fixed Steam Cranes.

These are the most suitable for a wharf doing a large trade; they should be so situated that any two cranes may plumb the two holds of a ship, and be placed such a height above the wharf as to prevent the sides or bulwarks of the ship fouling the jibs. The most suitable radius for the jibs is from 17 feet to 24 feet, The posts

upon which the crane works should be of wrought or cast iron, fixed in a base plate of cast iron; this plate must be bedded upon a good stone, resting on a sound brickwork foundation built in Portland cement; this will be more specially mentioned hereafter. The base plate has an internal rack or tooth wheel bolted on, having a conical face for the friction rollers to work on.

The jib is made of two wrought-iron slabs, and either with cast-iron distance pieces or diagonal bracing, or it may be made in the form of a riveted girder; in any case it should be spread at the base to the full width of the side frames of the crane, to give it *stiffness*, and prevent any chance of twisting, especially when the load is being swung. It is attached to the side frames at the base by a turned pin; the plates are stiffened at that point by an extra plate riveted on each side from 2 feet to 2 feet 6 inches long to prevent the pin from cutting, as well as to give extra strength. The top wheel for carrying the chain should not be less than 18 inches diameter for a 30 or 40 cwt. crane; it should have a deep plain groove for the chain to work in; it should run upon a fixed steel pin, not less than 2 inches diameter, passing through a wide boss, which should be bushed with gun-metal. The bottom pin which connects the jib to the side frames should also be of steel.

Two tie rods $1\frac{1}{2}$ inch diameter are connected to the pin at the wheel at top of the jib, and to the side frames. Rollers must be fitted between the jib and tie rods to carry the chain when slack, but the chain must not rub on them when at work. The carriage supporting the rollers also acts as a strut to the tie rods.

The side frames should either be cast or wrought iron, the latter being the preferable material, especially for large cranes; in this case all the bosses and bearings are made of cast iron, and are bolted to the wrought-iron side frames. These frames are bolted to a base plate or frame having a bored boss, which rests upon a collar on the post, and revolves on a turned part of the same. To the top of the frames is bolted a crosshead or stay piece, provided with a bored boss open at the top, working on top of the post, which is also turned at this point.

Machinery for Working the steam cylinders should be fixed horizontally on the outside of each side frame with the connecting rods working direct on to the crank pins, which are fixed in the first

working pinion on one side of the cam, and in the crank disk on the other. Two sets of wheels give motion to the barrel on which the chain is coiled; the centre of this shaft is kept as low as possible to keep the strain near to the base, and so save vibration.

The swinging gear is operated by right and left hand cones worked by lever and screw nut; these cones are placed on the crank shaft, which has two bevel pinions keyed on, working a crown wheel below; and by means of spur wheels which gear into the internal tooth ring on the base plate, the crane is easily and quickly swung as desired.

The first pair of wheels are patent frictional gear; the second pair, iron tooth wheels, pitched and trimmed. The man working the crane, uses one lever to start, stop, and lower, and with the other hand works the swinging gear. Cranes made upon this plan were designed by the Author some twenty-four years since, and are working to this time economically, and in a perfectly satisfactory manner.

Steam pipes, to supply the cranes on a wharf, are carried in a channel underground; junctions are provided for each crane; the details of these vary with the circumstances of the case.

Houses over Cranes.

It is advisable to cover the machinery and the man working both fixed and portable cranes with a house; this is made of sheet iron; much saving is effected by this as far as the machinery is concerned, and the man is able to work in all weathers without injury to his health. Objections have been raised to their use, upon the assumption that the men will not be so attentive, but after many years' practical experience of their working, the Author is able to say such fears are groundless.

Foundations of Cranes.

The foundations for cranes should have the greatest care. For 40-cwt. cranes, the holding-down bolts of the base-plate should not be less than 6 feet long, and 1½ inch in diameter, secured at the base

by cottars bearing against a cast-iron frame built in the brickwork. The brickwork should be built in Portland cement, and should rest on Portland cement concrete. The top stone for the base-plate of crane should be Yorkshire or Portland or other suitable hard stone, according to the locality; it should not be less than 12 inches thick.

Where the brickwork bases stand some height above the wharf-line, for the purpose of the jibs clearing the sides of the ships, they should not be less than 6 feet by 6 feet, to ensure perfect stability and to keep the machinery entirely free from vibration.

No special rules can be given as to the depth of the brickwork below the wharf, as it will vary with the nature of the soil and other considerations. In places where the soil is boggy or bad in other respects, piles must be driven, then sawn off level, and 6-inch planking spiked to the same; on this a good base of cement concrete should be formed, and the brickwork foundations built on it, finishing with a base stone as before.

Boilers in a Central House.

Horizontal multitubular boilers are the most suitable to adopt for a wharf, where space is usually valuable. They require no setting, take up little room, and are most economical in working. The power should be ample, no loss takes place, as before observed, from having the boilers of ample capacity; on the contrary, much economy is effected by this system in the consumption of coal.

The foundation necessary for the multitubular boilers is two piers of brickwork resting on concrete; on these the cradles to carry the boilers are placed. Steam pipes may be carried 600 to 700 feet from the boiler with very little loss of pressure; they must be well clothed, and be provided with expansion joints in suitable positions. Condense boxes must also be provided at various points for the purpose of keeping the pipes free from water. On the line of pipes, proper valves should be provided to shut off any portion not required; this saves loss of steam.

Cornish and Lancashire Boilers.—Either of these types of boilers is sometimes adopted when space permits. They are both economical in the consumption of fuel, and can be worked to high

pressures with perfect safety. When either of these types is employed, it is advisable to provide smoke-consuming furnaces—they not only effect much saving in coal, but get rid of the smoke difficulty and satisfy the smoke inspectors; this is an essential matter in the London district. The capacity of the boiler or boilers to supply steam for working the cranes and other apparatus, must be equal to at least 25 per cent. more than the total amount of steam required for the number of cranes or other apparatus that are likely to be at work at the *same* time. In all cases, one spare boiler should be provided. The feed apparatus should be in duplicate; the feed-water may be heated by a Green's economiser or by a simple heater, which may be partly heated by waste steam from the steam feed pump, and partly by live steam from the boilers.

Babcock and Wilcox Patent Water-Tube Boilers may be employed with much advantage to supply steam for cranes and hoists; they can be built to suit the shape of the room where they are to be placed, and possess the advantage that they can be passed through a smaller space or opening than any other boiler of the same evaporative power. No one part of the boiler exceeds 1 ton in weight; it will be seen by this it is readily portable. Repairs can be rapidly and easily executed. They are perfectly safe, working even under pressures to 200 lb. per square inch. Any ordinary stoker can attend to them. The consumption of coal does not exceed any type of the most economical boiler at present in use. Having had much experience of their working in places where the Author has adopted this form of boiler, he can with the greatest confidence recommend their employment.

For further details as to the different type of boilers, the reader is referred to the Author's book upon 'Pumps and Pumping' (E. and F. N. Spon), where the fullest particulars are given of every type in general use at the present day. As boilers are only an adjunct to cranes, space cannot be spared in the present work to describe them more fully in detail.

Portable Steam Cranes (Drawing No. 64).

These cranes are made upon the same plan as those before described, except that the whole apparatus is fixed on a trolly

and placed on wheels, which also carries the boiler, forming a counter-balance to the jib. In many cases, especially where the cranes are not working in direct lines, these are found the most suitable for the work; they are not quite so economical in working as to fuel as when several fixed cranes are supplied by one fixed boiler in the manner before described. In all cases, for safety, the crane, when lifting goods, should be secured by four screw clamps to the rails, as cases have occurred where the oscillation of the crane has thrown it over, and very serious results have taken place.

For light loads, cranes of this kind are made with the cylinders working direct on to the shaft carrying the barrel without the intervention of any wheel gear; they lift in these cases at the rate of about 200 to 250 feet per minute; the cylinders must be made large, and the stroke in the proportion of 2 to 1 of the diameter. The barrel for the chains must not be less than 6 inches to 7 inches diameter; 9 inches may be taken as a suitable size.

Heavy Loads.—Whore heavy weights have to be raised either by fixed or portable cranes, it is found more economical to have one or more special cranes for this purpose; in ordinary cases at wharves the maximum load seldom exceeds 4 tons. Cranes for this purpose are made with two motions, and fitted with clutch gear to use either power as required, according to the weight of the goods to be lifted. As a rule, taking the ordinary work of a wharf, it does not pay to provide a crane to lift more than 4 tons direct from the barrel; a movable block should be employed, and all the parts of the crane made of sufficient strength; a good margin of safety must be provided, when such heavy loads are to be lowered, by a brake.

10-Ton Travelling Crane (Drawing No. 65).

These machines are made by Messrs. John H. Wilson and Co., Limited, Liverpool; they are mounted on a truck, similar to those used on a railway, on four or six steel-tyred flanged wheels for running on the standard 4 feet 8½ inches gauge. The distance between the centres of the wheels is 4 feet 6 inches, the length of

the truck is 14 feet 6 inches, and the width 7 feet. The frame of the truck is formed of two steel-built girders, with suitable cross-ties, and is covered on the top with wrought-iron chequered foot-plates. When for use on a railway company's line, the truck is fitted with springs, buffers, couplings, &c., for running with the ordinary main line rolling stock. When only required for the purposes of a wharf or dock in a depôt, &c., the buffers, couplings, &c., are omitted. The base-plate of the crane, which is cast iron, is bolted directly to the truck, and is accurately machined for the reception of the roller-path and centre post. The side frames and top and bottom castings are made of cast iron, and contain the bearings for the various shafts, all the principal bearings being adjustable and fitted with brass steps and caps. The jib is constructed of steel plates and angles 13 inches wide at the bottom, and 8 inches wide at the top, and is spread out to the full width of the crane-framing at the bottom end, and suitably latticed to give great lateral stability; the jib-head pulley is 2 feet diameter and grooved for the reception of the lifting chain, and runs on a steel pin. The tie-rods are $1\frac{3}{4}$ inch diameter, and are attached at one end to the jib-head, the other end carrying a grooved pulley for taking the return chain for raising and lowering the jib, one end being securely anchored to the crane framing, and the other end wound on a grooved barrel, operated by means of a worm-wheel and worm, which is fitted with a locking arrangement to secure the jib in any position required. The radius of the jib is 16 feet, and the height above rail-level to centre of jib-head pulley is 23 feet. The engines for working the different motions are placed vertically, and are fixed to the side frames of the crane, and have two cylinders 8 inches diameter by 12 inches stroke, fitted with link reversing motion. The lifting motion is single and double purchase, the load being lifted on a single part of chain $1\frac{3}{16}$ inch diameter, and provided with a swivel hook; the speed of lift with the full load is 25 feet per minute; a quick speed is also provided for lifting lighter loads; a powerful combined screw- and foot-brake is fitted of ample power to hold the maximum load, the brake-strap being lined with wood blocks. The slewing motion is worked by means of double-friction cones of large diameter; the lifting and slewing motions are capable of being worked together or separately in either direction as required without reversing the

engines. The crane is also fitted with self-propelling gearing for travelling itself along the rails. All the shafting is of the best mild steel, and the pinions of best crucible cast steel, and are all accurately turned or bored, and secured by sunk keys. The boiler is of the ordinary vertical cross-tube type, 3 feet 9 inches diameter by 8 feet 6 inches high, with three cross tubes in the fire-box, and is constructed of Siemens-Martin's mild boiler steel throughout, all holes being drilled in place after the plates are bent in position. The boiler is tested by hydraulic pressure to twice the ordinary working pressure. The total weight of the crane is 35 tons in complete working order with boiler and tank charged, giving a load of nearly 6 tons on each wheel.

Portable Cranes, constructed on much the same principle, are made to lift from 1 up to 15 tons, and are made to suit varying conditions as to radius of jib, gauge of rails, &c., the former having been made up to 50 feet, with a height of 48 feet above rail level to centre of jib-head pulley. These cranes are generally made self-propelling, and are so arranged that the different motions, viz., lifting, slewing, and travelling, can be worked simultaneously.

15-Ton Block Setting Crane.

This machine is constructed by Messrs. Stothert and Pitt, Limited, for setting concrete blocks in position under water. The crane is capable of raising a maximum load of 15 tons a total height of 42 feet, with a maximum radius of 45 feet; the height from the rails to the under side of the jib being 22 feet 3 inches. A wrought-iron truck, running on eight tram-wheels, carries the crane and its machinery; a central post of riveted wrought-iron, built of plates $\frac{3}{4}$ inch thick, is secured to the cross girders of the truck; it is fitted with a wheel-race, with internal rack and swinging gear. The strut of the top jib girders is placed at an angle of 45°, and is continued in a horizontal line at the back of the post, at the end of which a vertical boiler is seated, acting as a counter-balance to the overhanging load. The two jib girders are framed together, and by means of a cross-head, turn on the top of the post of the crane; they are riveted to the two strut-girders which meet about midway between the post and the end of

the jib. At the junction of the struts, and at the top of the jib, two vertical struts well braced together are provided, at the top of which two rods are attached, and are connected at the top part of the crane post, and prolonged to the lower frame, and there connected at about the centre of the boiler. At the other end four tie-bars are also connected, and are attached near the end and centre of the jib. The central strut is braced from short transome-girders placed over the large diagonal struts. The machinery for working the various motions for lifting, racking, and travelling, is placed between the main strut and the post; wire ropes are provided to operate the traveller, and double chains $1\frac{3}{16}$ inch diameter to raise and lower the load. The cylinders of the engine are 10 inches diameter and 16 inches stroke. There are many advantages gained by the use of these machines, of which the following may be noted:—The amount of clear headway under the jib is more than any other type of crane. The jib, by its unique form of trussing, although 60 feet long, is made rigid without the employment of any considerable weight.

Titan Crane.

This powerful apparatus is used for pier and harbour work, for the lifting, moving, and lowering heavy stones, concrete-blocks, and other materials required during the construction of such works; they are made in several forms, but as they are of a special character, the Author has selected one made by Messrs. Stothert and Pitt, Limited, which is capable of raising a load of 27 tons. The machine in all its movements is operated and controlled by steam power, and is constructed with a lower truck- or bed-plate mounted on eight tram-wheels travelling on rails laid on the pier or quay; the length of this truck is 36 feet, and the width 25 feet. At each end are fixed two braced frames of wrought-iron, to which at the top part, are attached two trellis jib-girders; these project over the water from the side of the quay 23 feet. The framing and girders are strutted by cross trellis girders. The boiler is placed on top of the girders near the back frame, and behind this a counter-balance tank containing water, and weighing 30 tons, is situated. The engine to operate the lifting, traversing and travelling gear is placed in the front of and close to the boiler. The

traveller crab-motion runs on rails attached to the top of the jib-girders; motion is given by means of a longitudinal shaft from the engine; gearing is also provided to rack the load in and out as required. Chain gearing connected with the engine is also provided for the purpose of moving the machine on the rails.

The "Titan" is of sufficient width between the main frames to allow of two lines of railway of the usual standard gauge—4 feet 8½ inches—under it, on which the trucks carrying the concrete or other blocks travel. The engine is eight nominal horse power, and is supplied with steam at a pressure of 60 lbs. per square inch.

Block Setting Cranes, "Mammoth" Type.

This crane is for the purpose of concrete block setting for pier and harbour work; it is constructed by Messrs. Stothert and Pitt, Limited. The crane is capable of lifting a load of 50 tons at a radius of 20 feet minimum, to 92 feet maximum, the whole operation being performed by steam-power. A wrought-iron girder frame is provided, having legs or side frames, which are mounted on flanged tram-wheels, by which means it can be moved on rails placed at the ground line as desired. On the top of the frame a circular box girder is fixed, having a curb or race, 34 feet diameter, a corresponding girder is attached to the framing at the under part of the crane-jib, which runs on fifty-two friction rollers on the lower curb. The crane-jib consists of wrought-iron riveted girders.

The boiler, as well as the engine and gearing, are carried at the back end, forming a counter-balance to the load. Above the outer edge of the 34-feet curb, and thus 16 feet from the centre of the pin, a framed post or strut is provided; this frame is equal to the width of the girders of the jib, and to which it is riveted; three suspension rods are attached at each side to the top of the strut, and to three separate joints on either side of the jib. At the other side of the pin, and in the same relative position, another shorter framed strut is provided, two rods attached to the top of the main strut are connected with the girder near the centre of the boiler; two extra double minor tie-rods are also fixed, one to the main strut and one to the minor strut, the lower end of each being attached to the girders of the jib. The engine and machinery for raising the load,

racking in and out, and swinging, is much the same as that used for the "Titan," described at p. 115. The Author believes this to be the largest crane of this type in existence; it has worked in such a satisfactory manner that several of the same design have been built by Messrs. Stothert and Pitt, Limited, and used for like purposes.

Steam "Goliath" Travelling Cranes.

These apparatus are constructed on the same general form as those for hand-power, described at p. 157, except that for steam-driving they are more massive, and usually made of larger dimensions and to lift heavier loads.

The frame and girders of the traveller are either of timber, when used for temporary outdoor work, or of wrought-iron. Selecting the last type, they are constructed with cross-girders of wrought-iron plate in the box form; these are attached at the ends to short longitudinal girders, also of the box form. Four wrought-iron bracketed legs or standards are riveted to the under side of the main girders and to longitudinal box-girders at the base, which are mounted on double-flanged tram-wheels, on which they travel on the rails placed at the ground line. The tram-wheels are placed some distance apart in order to give steadiness to the frame. At the lower part of the standards gusset struts are provided at the four sides, and are riveted to the side frames and also to the base girders; these materially add to the rigidity of the framing. A footway is provided at top of the girders on both sides, and is protected by hand-railing.

The span between the rails is made sufficient to bridge over one, two, or three lines of railway of 4 feet 8½ inches gauge each; in the latter case it will be about 38 to 40 feet; this enables locomotives and trucks to pass under the traveller, and the contents of the latter to be lifted, delivered, or deposited elsewhere.

There are two systems of steam machinery for lifting the loads, viz.:—1. By a steam hoist with a boiler attached, contained in a frame running on rails on top of the cross-girders of the traveller. 2. By a steam-crane and boiler provided with a jib of sufficient radius to plumb the required distance, also running on rails on the girders. For use in docks, and at railway and other depôts, the latter plan is

to be recommended. The crane is of the same construction as described for either of the portable cranes at p. 112. The machinery as well as the boiler should be protected by an iron house. It is propelled on the rails of the girders by the engines. The loads lifted will depend upon the work to be done, and may vary from 2 to 10 tons, or even more in special cases. It will be noticed that a "Goliath" of the type described is most convenient for use at a dock, wharf, or quay, more especially where the floor space is usually limited, and is very valuable. No permanent obstruction is caused, and the expensive foundations necessary for cranes are avoided. In addition, a further advantage may be noted in the fact that the jib lifting the load being placed so high, it is clear of most obstructions, and is able to land the goods at a higher level than in the case of cranes fixed at or near the level of the wharf. No. 2 system of working also has the advantage that the loads can be raised to a much higher level, and can be swung some distance without having to move the traveller frame.

Steam Navvy.

This powerful machine is used for excavating earth, for railway, canal, and other purposes. It is constructed with a crane-jib, in somewhat the same form as a steam-crane; the whole machine is mounted on a truck running on four wheels on railway metals; the gear for raising the loaded bucket, as well as the swinging arrangements, are about the same type as usually employed for heavy cranes. The base-plate carries a vertical boiler, which also acts as a counter-balance to the load. The girder or arm carrying the bucket for excavating is placed at about the centre of the jib; it is provided with a toothed rack at the back into which a pinion gears, and at the centre of the bucket, by means of two long links, the crane-chain is attached; a rod is provided reaching from the man on the footboard of the crane, and by levers in connection with the bucket gives power to discharge it when full, after it has been swung to the required spot. The bucket can be projected to varying distances from the end of the jib by the chain and pinion motion working in the rack on the girder. The buckets for sand

and gravel contain $2\frac{1}{4}$ cubic yards, two being sufficient to fill an ordinary contractor's earth wagon. About 2,000 cubic yards of earth can be excavated in ten hours, but in working the average quantity is, however, much lower than this. The working expenses are stated to be about 30*s.* per day, or about ·50*d.* per cubic yard excavated. It is needless to say these are very powerfully made machines, and are proportionately heavy, and for this reason cannot often be used on soft or boggy ground. As a machine of this size costs about £1200, they can only be employed in heavy work.

Excavating Machine.

Another machine for excavating earth, such as from the side of a canal, is made somewhat like a steam ballast dredger. The machine is carried on a truck mounted on wheels, which runs on railway lines; it is provided with a jib to which, by means of chains, the lower part of the endless chain of buckets is attached; the other end is carried on a cast-iron drum and keyed on a spindle which revolves in bearings attached to the frames of the machine. The distance between the centres of the top and bottom wheels is from 40 to 45 feet. In machines of this size they usually carry twenty-five excavating buckets. The boiler and engines for driving this apparatus are carried by the truck. The operation is much the same as in the case of a ballast dredger, the buckets cut the earth, and take it up above the bank, where it is discharged into a hopper, and thence into the contractors' trucks. This machine can move, raise and discharge about 1500 cubic yards of earth in ten hours. The average working expenses per day is about 60*s.*, or equal to about ·44*d.* to ·50*d.* per cubic yard excavated. The weight of the machine is about 80 tons, and for this reason it cannot usually be employed in places where the ground is soft. The cost of such a machine is about £2,300, which would preclude its use in any but the heaviest class of work.

Steam Dredging Machines.

These machines may be fairly considered to come under the head of lifting machinery, as they are employed to raise ballast, sand soil, etc., from the beds of rivers, harbours and docks. They are also used to cut new channels and deepen and maintain existing rivers and waterways, etc., and are made of sufficient power to dredge up to 800 tons per hour in ordinary material. A machine of this power is made by Messrs. Simons & Co., of Renfrew, and as they are of a very special character, the Author considers it would be better to describe one constructed by these specially experienced makers.

The whole apparatus is contained in a float, barge, or vessel, which also carries the engines, boilers, and dredging machinery. The apparatus consists of a double endless steel chain, to which is attached at intervals on each side heavy wrought-iron or steel buckets. The chains revolve on a drum keyed on a spindle, which is carried in bearings on the side frame of the machine; these frames are attached to a powerful cast-iron bed-plate, which also carries the rest of the machinery, and is bolted to the deck of the vessel. At the lower part of the chain another drum-wheel is provided, over which the two chains pass; the two drums or wheels for the chains are connected by wrought-iron framing. At the pin on which the lower wheel runs a chain is attached, and by means of a barrel, on to which it is coiled, it is raised, lowered, and adjusted to suit the level of the bed of earth against which it is required to work. The machinery to operate the endless chain carrying the buckets for raising as well as lowering is situated on the bed-plate before named, and is driven by engine power. One man can control the driving apparatus, suitable gear being provided convenient to his hand. The speed of the drums of the chain is eight revolutions per minute, being a speed of 48 feet at the chains, at which speed the dredger will raise 8000 tons in ten hours, the height of the lift being equal to 35 feet.

The boilers for supplying steam are two in number, and are 12 feet diameter and 10 feet 6 inches long. The pressure of steam used is 90 lbs. per square inch. The engine cylinders are 20 inches

and 42 inches diameter, and 30 inches stroke; they are built in the vertical form; a train of wheels communicates motion to the top drum on which the endless chain revolves.

The vessel containing the whole of the machinery is 180 feet long and 36 feet beam, and draws about 12 feet of water. When fully equipped, and in working order, the dead load is 800 tons. It is propelled by steam-power, by a screw which is driven by the general engines.

The cost of dredging by the apparatus in gravel or sand is about 2½*d.* per cubic yard, this includes transportation to place of deposit, interest on the first cost of the machine as well as all labour, fuel, wear, and repairs to the machinery.

Priestman's Steam Crane and Patent Grab-Bucket.

These machines are used in conjunction with a steam-crane to raise ballast or other material under water. The crane is specially designed for the purpose with a view to bringing the two chains required under the easy control of one man and working at a high speed. The bucket is made of steel plates in two sections hinged at the upper part, and is provided with cutting claws or teeth on each side of the bottom; an arrangement of levers in connection with the chain led from the crane causes the closing of the two halves of the bucket when it has dug out and grabbed the earth. After it is raised the requisite height, it is swung over the railway trucks, or other receptacles, and by means of levers and gear connected with the crane the bucket is opened at the bottom and the contents discharged. As much as 250 to 300 cubic yards of gravel or soil of like kind can be excavated in about ten hours. A special design of grab-bucket is made which can be worked by an ordinary steam-crane, with suitable provision made for the control of the opening and closing of the bucket. They are made in several forms; for lifting grain or mud no teeth are required; for clay, and for dredging rivers or canals with muddy deposit, they are made as an open grid, more or less close, according to the materials to be dealt with. The buckets usually contain 1 to 1½ cubic yards. The quantity lifted per hour is 75 tons gravel, &c., and with clay about 50 tons.

Apparatus for Slinging Goods when Unloading Vessels by Cranes.

Wrought-iron Crosses, with four sets of slings attached to the same, are used for the purpose of raising small casks containing pork, currants, sugar, soda, etc. They are constructed in the form of a cross, provided with an eyelet at the centre, by which it is suspended from the hook of the crane-chain. At each corner a chain-sling is attached, the ends of each are provided with a ring, which carries double grab-hooks, by means of which the casks are held.

For lighter loads, a wrought-iron ring, with six or more chains attached, is suitable for raising small bags or packages. When bags or sacks of materials have to be raised, each chain has a large ring at the end to form a running noose; in other cases a hook only is necessary.

A safe sling, designed by the Author some years since for raising casks of wine, oil, etc., consists of one chain with a large ring at one end and a hook at the other; this chain is put round the cask at one end, passed through the ring, drawn tight, and then round the cask at the other end, the hook being caught in the chain, leaving sufficient space and slackness for the crane-hook to take hold of. It will be seen such a sling cannot slip, and the strain of the crane only tends to tighten it upon the cask. This kind of sling has been in successful and safe use for many years at some of the largest wharves and at other places in London and elsewhere.

Sugar when in loaves, and all small sundry packages, are lifted quickly and safely upon a scale board attached to the crane-hook by four small chains, and suspended from a wrought-iron cross fitted with a ring at the centre.

In cases where the goods have to be warehoused after they are taken out of the ship, they are best lifted in a box running on three wheels, the front one being made to swivel; when landed, they can be easily run to any required point, and attached to the hook of the warehouse crane and lifted on to the floor required. Spare boxes are used, so as to keep the cranes continuously at work.

Steam Warehouse Cranes and Hoists.

The general arrangement of jibs and steam-hoisting engines is shown in Drawing No. 67. The handle for working the hoist must in all cases be placed at the loopholes to enable the man to see the load he is raising or lowering. Whenever possible the hoists should be placed on a floor below the highest level where goods are to be delivered; this allows proper lead for the chain, and prevents undue strain, as the chain is coiled on the barrel. There are various kinds of hoisting engines; suitable forms of which are described below.

Drawing No. 66 shows a hoist with two oscillating steam cylinders, 6 to 7 inches diameter, by 12 to 14-inch stroke, inclined at an angle, and working direct on to crank discs. The cylinders are fixed outside each side frame. One pair of spur (tooth) wheels, pitched and trimmed, give motion to the shaft carrying the barrel on which the chain is coiled. The valve motions are worked by links, keyed on to one weight shaft, to which is also keyed the hand working lever. The man operating the crane can start, stop, and lower by means of this lever; there are no clutches to throw out, shocks and consequent fractures are thus avoided.

To swing the Jibs two small steam cylinders may be used, with a chain fixed to a grooved wheel keyed on the post; this is on much the same plan as for the hydraulic cranes. As a rule, however, the jibs are swung automatically.

Hoists are also made like the above, but with the cylinders fixed horizontally (see Drawing No. 68). For the purpose of running both ways, either two eccentrics to each cylinder are used with link motion, or a special valve box, admitting steam on alternate sides of the piston, is provided; this plan has been working for some years, and is most efficient in its action. Swinging gear, when required, is the same as before described. This is the most direct and efficient, and saves much friction, as against the clutch and gearing plan, which the Author cannot recommend; it also does away with the risk of fracture from the shocks they would be liable to when the latter plan is adopted.

These kinds of hoists take rather more floor room, but work with less vibration than those previously named.

Hoists are made upon the plans of Nos. 66 and 68, but with the cylinders working direct upon the crank pins. They usually run at high speeds, say, from 200 to 250 feet per minute, and are very suitable for raising cork, wool, esparto grass, tea, and other light goods, especially when packed in small cases or boxes. The diameters of the cylinders, as compared with those before described, should be increased, and the strokes decreased; all the other parts of the hoist should be strengthened to stand the extra shock from the increased speed.

In all the above instances, the Hoisting engine should have a good bedplate, and be securely fixed, to save vibration. The bedplate should be lipped all round the edge to take the condensed water, and so keep the floors dry; in addition to this, it is advisable to form a lead safing with a raised edge all round under the hoists, in case the condensed water overflows the bedplate,—the goods on the floors are not then damaged.

Hoists are made with fixed cylinders, both in the vertical and the horizontal forms with patent frictional gear, and may either be single or double geared. One lever starts, stops, and lowers; the brake is always on, and is taken off when raising or lowering. This is a very safe plan, and often prevents accident. The work must be of the highest class, the shafts made of steel, and all the parts strong, to avoid any springing or vibration.

Hoists have also been made to operate Warehouse Cranes, where the load is light, and the lift does not exceed 10 feet, by direct action from a steam cylinder, the stroke of which is made in this case 2 to 1, with a movable pulley. The piston rod should be extra large, to be rigid and enable it to stand any sudden shock; the cylinder can either be fixed horizontally or vertically; the pressure of steam should not be less than 50 to 60 lbs. per square inch, in order to work them with economy; care must be taken to protect the cylinder and pipes to prevent condensation of the steam. Arrangements are made in the valve gear to pass the exhaust to the reverse

side of the piston, to keep it warm, the waste steam being driven out at the next stroke. This is somewhat complicated, and cannot be described in detail, as space will not admit.

There are many other forms of hoists; in addition to some of a special character hereafter described; but the above are specially recommended by the Author as those with which he has had many years' experience, and because he can bear testimony as to the simplicity of the parts and also as to their efficient working.

Steam Hoists and Warehouse Cranes for Wool, etc.

During the last twenty to twenty-two years the number of warehouses for storing tea, wool, esparto grass, &c., have much increased in London. Several good forms of steam hoists have been specially designed for the purposes of rapidly unloading the vans and storing the goods on the various floors of the warehouses. The Author will now describe some of the best kinds of hoists for this purpose, and the arrangement of jibs, and other parts, most advisable to adopt in such cases.

Hoists are made on much the same plan as described for Nos. 66 and 68, the crossheads of the piston rods of the cylinder being connected direct to the crank discs keyed on the shaft carrying the band. The cylinders are oscillating, 8 inches in diameter, by 12-inch stroke. The barrel for the chain is 12 inches diameter by 2 feet 9 inches to 3 feet long, and is capable of coiling about 50 feet of $\frac{5}{8}$-inch crane chain without any overlap; this is about equal to the average height of the top floors of most warehouses in the London district. The ports of the cylinders are made of free area, and all parts very strong to stand the rapid work.

No. 1 *Form of Hoisting.*—The cylinders are made oscillating as described for No. 66, and either worked by link motion, or by a central reversing box as described at p. 123. The side frames of the hoist are fixed to a bed-plate in the same manner as before, and lipped all round to catch the condensed water. In some cases the side frames and bed-plate are fixed direct on the wall of the building, with a leaded trough under same, to catch the water as before mentioned.

No. 2 *Form.*—The cylinders in this case are fixed vertically. The connecting rods work direct on to the crank discs keyed on the barrel shaft; the sizes of the cylinders and barrels are same as above. The valve motion is worked by a central reversing box, and in both cases by means of one lever, the man working the hoist can start, stop, and lower the load, and has perfect control over the same.

An arrangement can be made by special gear to the barrels to stop the engines when any desired floor is reached.

The Best Position for the Hoist is on the floor *below the highest floor* (see Drawing No. 67). This, as before stated, gives sufficient lead to the chain, and allows it to coil regularly and closely upon the barrel, without the aid of guide rollers, which should always be avoided whenever possible.

The Jibs should be made of two flat slabs with cast-iron distance pieces riveted together, the average radius for jibs suited for such purposes is about 7 feet 6 inches to 8 feet; wherever possible the angle of the jib should be 45 degrees. The top wheel should be about 14 inches in diameter, provided with a wide boss, and should work upon a $1\frac{3}{4}$-inch diameter steel pin. The wheel should have a deep and wide groove, and be turned at this part for the chain to work easily in, and thus save friction.

The Carriages for the jib at the top and bottom should be fixed to a cast-iron back plate and be bolted to the wall by four bolts passing through to two back plates on the other side of the wall, and secured by nuts. This preserves the bearings in exactly relative positions, and also adds rigidity to the wall at these points, preventing damage to the same, and also vibration to the machine.

When the warehouse is a new building, the piers where the cranes are fixed should be built in cement; and in places where the jibs are fixed near the top of the building, a good heavy parapet or cornice is of advantage to keep the wall steady.

The pins of the two leading wheels at the top bearing should be at right angles with the chain when taut. The grooves should be made wide, and the flanges of sufficient depth to just clear each other; this prevents the chain getting jambed when it is slack and the load is off. One or more guide rollers must be fixed between the head of

the jib, and the above rollers, for the chain to rest on when slack; the chain should not touch the rollers when the load is on. These rollers should be bushed with gun-metal, and run on turned steel pins, $1\frac{1}{4}$ inch to $1\frac{1}{2}$ inch diameter.

Arrangements should be made for oiling the top and bottom bearings of the jib by means of small pipes passed through the walls. At the lower bearing the crane post should rest on three steel discs fitted to the step plate; these discs should be coned on both sides to reduce the friction.

The Chain should be $\frac{7}{16}$ to $\frac{1}{2}$-inch diameter, according to the load, and be provided with a spring hook and a ball fixed a short distance above the same, this must be leaded on to the chain to prevent it shifting. The weight of the ball should be sufficient to overhaul the chain when running down without a load. The chain of a steam crane or hoist working at a rapid rate should be changed at least once per month, and be most carefully examined in order to detect any flaws in the links, it should be passed through the fire and well annealed. When there is any sign of wear in the links the chain should be reversed; in all cases spare chains should be kept in readiness in case of emergency.

Swinging Gear is not usually attached to hoists of this class, on account of their rapidity in working. The Author designed, some years ago, an arrangement of springs, levers, and counter-weights to keep the jibs at any required angle. A guard chain is fastened at one end to the front of the warehouse wall, and at the other to the head of the jib; the length of this chain is, of course, adjustable to suit the position of the jibs. The gear works perfectly, and the goods are swung more rapidly by it than by the steam cylinders before described.

Spring Buffers are fixed on the warehouse wall at the level of the pin of the grooved wheel, to take the shock of the jib when pulled in by a slack rope directly the load is landed; the self-acting gear pulls the jib out again, as the chain descends for the next load. The jib may be kept at any angle desired by a special arrangement of springs; these buffers stand heavy wear, and are perfectly successful.

The speed of these hoists is about 250 feet per minute. The

weight of each bale of wool is about 3 cwt. The quantity unloaded at a large warehouse in London by five cranes is about 1,000 bales of wool in eleven hours. Each crane requires the attendance of two men—one at the hoist, and one to take off and wheel the bales away.

The boilers to work the cranes may be either multitubular or Cornish; if the former a less diameter and length will do than in the latter case, and where space is an object this wants careful consideration.

At another large wool warehouse they had five cranes capable of lifting 20 cwt. each, and one to lift about 5 cwt.; they were worked by one 20 nominal horse-power boiler, at a pressure of 55 to 60 lbs. per square inch. The coal consumed is about 2 cwt. per hour, at a cost of about 16*s*. per ton, delivered into the boiler house.

One crane working ten hours will land 120 tons of goods, with an average lift of 20 feet; this allows time for clearing the goods away. Comparing this with hand power: to lift 12 cwt. 20 feet, five men will be required, and about 168 cwt. will be lifted per hour.

The cost of coal for five or six such cranes, in full work, will be about 4*s*. 6*d*. per day of ten or eleven hours (when coals are at an average price, say, 16*s*. to 18*s*. per ton). This assumes that all the cylinders, pipes, and other parts have been well protected by felting or composition, and that every care has been taken to avoid loss of steam.

The work done varies at different places, and much depends upon the class of work. Steam of the required pressure is always ready at a wharf or warehouse, so as to be able to clear any goods from craft that may arrive without notice.

The Author thought it would be advisable to give data from actual work performed, rather than any theoretical deduction from any experiments spread over a short time. He had an opportunity some years since to test the difference in cost between hydraulic and steam power, the result being much in the favour of the latter. It is needless to say the saving effected between steam and hand power is very large; in all such cases the whole of the expenses should be taken into account in the same manner as before named for hydraulic machinery.

The boilers for the supply of steam should always be placed in a separate fire-proof building, so that the rates of insurance are not affected. In some cases, where only two cranes are worked, a gas engine or boiler can be used with advantage, although the cost of working, as elsewhere stated, is much more than with a steam boiler. The gas engine is, however, far more economical than the gas boiler, and possesses this advantage—there is no risk of explosion.

Portable Steam Hoists.

These machines are suitable for employment in temporary outdoor works; the Author has adopted them with much advantage during the construction of large buildings of the warehouse type. Great saving in time and labour is effected in the raising of materials, the men are kept well served, and the laborious work of carrying stone, bricks and mortar, &c., up and down ladders, is avoided.

The best form of construction is to place a vertical cross tube boiler on a cast-iron truck mounted on four wheels; in front of the boiler the hoisting-engine may be placed, the most suitable type is that shown in Drawings Nos. 66, 68, mostly used for warehouse hoists. The lifting barrel may either be placed direct on the crank-shaft, or, as an intermediate shaft with a pair of spur wheels, may be employed in the manner shown; in the former case the steam cylinders may be 7 inches diameter and 14 inches stroke, and in the latter 6 inches diameter and 12 inches stroke, the wheel gear being in the proportion of 5 to 1. No swinging gear is required. The pressure of steam should be 45 lbs. per square inch, and the speed of the chain about 200 feet per minute. The lifting is performed by a chain passing from the barrel of the hoist over a grooved wheel placed about 8 feet above the highest floor or stage to which the loads have to be raised. It is advisable to carry the chain direct from the barrel to the top wheel without the intervention of leading wheels, as these much increase the friction, and also the wear of the chains. In some places a separate boiler may be available, from which steam may be obtained to work the hoist; in this case the (portable) boiler may be omitted on the truck. There are several systems of raising materials by these hoists:—

1. By forming a shoot or well-hole the whole height to be raised. The stones, bricks, as well as the mortar, are put into barrows, which are attached to the lifting chain by three slings and specially-made hooks.

2. By forming rough framing provided with two T-iron guides, and a cage running between the guides on which the barrows or trucks of stone, bricks and mortar are run on. This latter plan is the most satisfactory; the cost of erection does not much exceed the shoot in No. 1 plan.

Trucks for carrying bricks as well as mortar should be made of iron, circular at the bottom, hung on three wheels, the front one being made to swivel. The body of the truck should be suspended on trunnions, so as to easily tip out the contents.

Portable Hoists may also be driven by Brotherhood's three-cylinder engine, attached direct to the barrel, in the same manner as for the hydraulic hoists described at p. 67. This is a very compact form, and not more expensive as to first cost than the engines named above; it possesses the advantage that the engine is entirely enclosed and so kept free from dirt and dust, much less wear takes place, and from the simplicity of construction it is not so liable to break down; all parts of the engine being balanced, they work with less shock and vibration than an ordinary engine.

Hoists driven by Willans' Engine.—The barrels may also be attached direct to the crank-shaft of one of these engines; all working parts being enclosed, as in the case of the last-named engines, they are thus kept free from dirt and dust. The cost of this type of engine is somewhat more than the ordinary kind.

Warehouse Cranes driven by a Fixed Engine.

Where several cranes are placed in one line, or on one side of a warehouse, the following plan is sometimes adopted. This consists of one fixed engine, with shafting, connected to barrel hoisting gear either worked by cone clutches in the way described at p. 132, or by patent frictional gear (see Drawings Nos. 71, 72, 73). The cost of working on this plan is much increased on account of the extra friction of the shafting and gear, and the heavy work thrown on to the engine by the cranes situated near the end of the

shafting. If any hoists or lifts are used, they can also be driven off any shafting near them. The Author does not recommend this plan for warehouse purposes, unless under special circumstances, where the systems before described cannot be adopted, or where there happens to be an engine near which is used for other purposes of the establishment. It must always be borne in mind that the power should be placed as near as possible to the work to be done; hence great advantage is obtained by the use of self-contained hoists, over any system worked by shafting and gear.

In places where a boiler cannot be fixed, steam is sometimes hired from an adjoining factory, and where power is only occasionally required, it is a most economical arrangement. The rent is usually charged at per week of sixty hours, according to the time the machinery runs; a fair charge for this is 10*s*. per week of sixty hours per I.HP. when used regularly, and 145 when only occasionally required.

In cases where special hoisting engines are not adopted as described at p. 123, and when the hoisting apparatus has to be driven by engine-power used for other purposes, the following machinery is suitable.

Barrel Driven by Patent Frictional Gear.

Barrel gear for raising hops, malt, sacks of rice, corn, flour, &c., the above apparatus is to be recommended, especially where steam power for other purposes is required for carrying on the business (see Drawing No. 71); it is constructed in the following manner:—

The barrel is generally made about 9 or 10 inches in diameter, the length being proportioned according to the height to be lifted; the large friction wheel is keyed on the barrel shaft; a small counter-shaft pinion carries the smaller wheel, or the counter-shaft is driven by belt from the main shafting, or the pinion may be keyed on the main shaft. The shaft of the barrel is provided with eccentric bearings, and by means of levers connected to each end, the two wheels are brought into contact, and motion is given to the barrel.

The brake gear consists of a solid block of beech turned to fit the periphery of the wheel; this is fixed in a cast-iron box or shoe, and by means of screws is made capable of adjustment as it wears; much care must be used in fixing the brake-box rigidly; it must not

be allowed to spring in any way. A counter-weight is provided to keep the large wheel on the brake.

To work the barrel only one rope is required; the man *pulls* into gear and lets the rope go when he wishes to put on the brake, and when lowering the load he holds the rope slack.

Self-Acting Stopping Gear is attached to prevent accident, and stop the lifting at the highest and lowest points of its travel.

All the work must be of the best class, the spindles made large, and the bearings equal to at least two diameters in length; the plummer blocks must be firmly fixed, and the timbers strong, to prevent any springing or vibration. The *success of the working entirely depends upon the careful proportion of the parts and perfectly true workmanship.* This type of apparatus was improved in many essential respects some years since by the Author, who has used it largely at many important works carried out under his direction.

Double Barrel Cone Gear (Drawing No. 73).

Barrels for raising goods are constructed in much the same manner as before described, except that they are driven by cone clutches instead of frictional gear. In the example shown in the drawing there are two barrels constructed in the following way. At each end of the barrels they are provided with cones, at the centre a fixed two-faced cone is keyed on the shaft which is common to the two barrels. At either end a sliding cone working on feathers on the shaft is thrown in and out of gear by two clutch levers, directly they are thrown into gear the two parts of the clutch at the ends of each of the barrels grip and are set in motion. The barrels are bushed with gun metal at the bosses and run loose on the shaft. Automatic gear is attached to strike out the cones when the highest point is reached. The shaft is driven by belt gear, either barrel can be thrown in and out of gear independently. The goods are raised by a rope or chain, if the former, one made of leather is preferable. The barrels are 10 inches diameter and about 24 inches long, the cones 21½ inches diameter, and the shaft 3½ inches diameter, the speed of the lifting rope or chain is from 200 to 250 feet per minute. The amount of work to be done will decide whether double

or single barrels, as shown in Drawing No. 72, and hereafter described, should be employed. This system of lifting by barrels is one of the most rapid means in use at the present day. When the hoists are placed some distance from the shafting and gear of the place it is advisable to adopt hoisting engines as before described.

Cone Barrel Hoisting Apparatus.

This gear is for the purpose of raising sacks of corn, flour, beans, peas, &c., as well as bags and bales of wool, rags, hay, grasses, and like goods. The details are shown in Drawing No. 72; which also apply to the double barrel gear, described at p. 132. It is constructed with a hollow barrel, 9 inches or 10 inches diameter and about 24 inches long, provided with a cone at each end 17½ inches diameter, the angle of the cone is 45°; this requires much care, as on the proper angle and fit of the cones very much depends the accurate working of the apparatus. The barrel is bushed with gun metal at each boss, and runs free upon a shaft 3½ inches diameter. At one end, at A, a cone is keyed on, and at the other end, at B, a cone clutch sliding on a feather on the shaft is provided. A lever, C, fitted with gun-metal nogs, is also provided, and by its means the clutches at both ends of the barrel are brought into gear. A break wheel, D, 28 inches diameter, is formed on one of the cones on the barrel; this is fitted with a wrought-iron brake strap lined with wood, the lever is weighted to keep the brake on; it is released by means of the hand rope. Automatic gear is arranged, by which means the cone clutches are thrown out of gear and the brake put on before it can overrun the highest point of the lift. Either a hemp or hide rope or a crane chain may be used; either of the former, unless much exposed to the weather, is to be preferred. For raising weights of 10 cwt., this should be 3 inches circumference in the case of ropes, and for chain ½-inch diameter is sufficient. The speed of the lifting rope or chain is about 200 to 250 feet per minute. The apparatus can either be constructed with a single barrel as shown, or a double barrel, as in the last example, according to the work to be done. In granaries, maltings, and breweries, the men acquire, after some practice, the most complete control over the apparatus, and can manipulate it at will.

The exterior of the barrel should be turned, and the length made sufficient to wind on the whole of the rope or chain without any overlap, allowing sufficient length for two or three laps on the barrel when it is fully run out. All the fixings of the bearings and other parts must be rigidly made, as no deflection or vibration must be permitted. The shaft of the barrel may be driven by tooth-wheels or pulley and belt gear; the latter is usually preferred when the driving gear is under cover and not exposed to steam or vapour.

Slack Belt Gear.

The barrel is made as before, a large double-flanged pulley is keyed on the same shaft. It is worked by a slack leather belt, and is driven direct from any convenient shafting. It is brought into gear by a long lever provided with a small flanged tightening pulley at the end. The barrel shaft also has a brake attached, and is provided with brake lever gear and rope. The working lever has a counter-weight to take it out of gear directly the man operating it lets go the working rope, and at the same time the brake can be put on.

This plan is only suitable for one or two sacks of corn, flour, &c., and is usually made to lift at a high speed, and in some cases is arranged with a double chain, one on each end of the barrel, to coil off and on; the end of each chain has a large ring to form a running noose for the sacks.

The pulleys to give motion should be large in diameter, wide and turned (but not too smooth) on the rim and edges of the flanges; and should be coned to give a grip to the belt, which should be ½ inch to 1 inch less in width than the distance between the flanges of the pulleys. It is better to avoid lacing this belt; it should be riveted at the joints, or strap fasteners may be used. It is advisable to examine the belt occasionally, to see of the joints are perfect, as otherwise there is a liability to accidents if the belt breaks. Stout single belts are the most suitable; they are more pliable, and give a better bite or grip on the pulleys than double belts.

Self-Acting Throwing-Out Gear is also provided for this apparatus of the same description as before named.

Barrel Apparatus is usually fixed in pent-houses overhanging

the road or waterway, the floor of the house having two sets of oak flaps, hung on leather hinges (where the lift is double), with a hole for the rope to pass through. The timbers of this house should be made rigid, and fitted to stand hard work, so as not to communicate any vibration to the building. The Author advises that these projecting timbers, or jibs, should be carried some distance back into the building, and be framed into strong timbers, and properly stayed and strutted. The sides of the pent-house should be enclosed, to protect the men from the weather when working. The quickest method of working is to raise one or two sacks at a time. Much loss of time takes place when more are raised, both in putting on and taking off the load.

The speed of the chain or rope is usually 200 to 250 feet per minute. When chains are used they should be $\frac{1}{4}$ inch to $\frac{5}{16}$ inch in diameter, short link, with a round ring at the end to form a loop for the sacks. When ropes are adopted, they should be made of leather, as they are better able to stand exposure to the weather.

Steam Capstans.

These are useful in yards and depôts; they are made on much the same plan as the hydraulic capstans described at p. 38, except that there are only two cylinders, and the valve arrangement is somewhat different. All the pipes, cylinders, and steam chambers should be coated, and the pipes kept free from condense water by the use of condense boxes, which should be carefully adjusted. By means of leading pulleys, trucks, &c., can be drawn in any direction, as in the case of the hydraulic capstans. With regard to the steam pipes, see remarks at p. 155, on steam cranes, which equally apply in this case.

There are many other kinds of steam lifting and hauling apparatus capable of being applied in many special cases; they are not, however, as a rule, of sufficient importance to need a description here.

Electric Power Hauling and Lifting Machinery.—Electric power capstans are made as far as the upper part, viz., the base plate, revolving head and spindle, in much the same manner as the hydraulic capstan described at p. 38. The vertical spindle on which

the head is keyed is carried in a bearing on the base plate, and also in a lower one placed in a frame attached to the underside of the base plate. On this spindle and between these bearings, either a frictional or spur wheel is provided, which gears into a corresponding pinion keyed on the armature of the motor.

The Electric Motor is attached to the under part of the base plate, and is encased to keep it free from dirt and dust. The size of the motor is proportioned to the work to be done; it is usually worked at 80 volts, and should be capable of giving a sufficient quantity in ampères to allow a slight margin of power. The current is obtained from any convenient wire or conductor, and is first passed through a frame of resistance coils, from which, by means of switches, the requisite power is conducted to the motor. A separate switch is provided for starting and stopping the machine. In cases where these capstans are placed in isolated positions, electric power is very convenient for working them, especially in instances where neither steam nor hydraulic power could be conveniently applied.

8-Ton Electric Power Wharf Crane.

This crane is placed on the wharf at the river side at Messrs. Willans and Robinson's works at Thames Ditton, Surrey; the Author believes this is one of the first instances in which electric power has been adopted for raising such weights. He had the privilege of seeing the working of the crane. The loads are handled with the greatest facility. Arrangements are made in the gear for raising light loads at a quick pace. The crane is constructed in the following manner:—The post on which the crane turns is of wrought-iron, and is fixed in a base plate, resting upon the stone and concrete foundation. The framing carrying the barrels, and all the lifting and other gear, is also of wrought iron well framed together. The jib is 24 feet radius, and is formed of two channel iron girders which are attached to the side frames of the crane at the base; and at the top carries a chain wheel 2 feet diameter; an extra grooved wheel is provided for the wire-rope to run on, by which the light loads are raised. The jib can be raised and lowered so as to alter the radius as required, the cheeks are strongly stayed,

and carry guide rollers for the chain to rest on when slack. The gear consists of fast and loose pulleys (driven by belts), which are keyed on to spindles having spur, bevel, and worm wheel gear attached. The crane is swung by gear of the same description. The lifting chain is $\frac{3}{16}$ inch diameter at the link, and the chain for raising and lowering the jib is $\frac{3}{16}$ inch diameter. An extra barrel is provided to coil the wire rope used for light loads.

The Electric Motor is placed on the movable bed plate at the back part of the crane; it is about 8 B.HP., and uses a current of 90 ampères at 80 volts; it is wound as a shunt-motor, so as to be self-governing.

The motor is made by the Electric Construction Corporation, Limited. The power is obtained from a conductor led overhead, and taken down at the post to a frame of resistance coils. A switch is provided to vary the speed according to the work to be done; another switch is also employed to start and stop the motor. The magnet of the motor is separately excited. The speed of lifting and swinging is the same as in steam cranes. The cost of working is much less; no exact trials have, however, been made as to this at present. As this crane is placed some distance from the main boilers, some loss would usually take place by condensation in the steam pipes, especially when the crane was standing.

The crane was made by Messrs. Grafton & Co.; it is a substantial piece of work, and without any unnecessary complication in its working parts. The experience of the working has been very satisfactory; the firm have extended the power for driving other machines with equal satisfaction.

Electric Power Hoisting Engines.

These engines, except as to the steam cylinders, which are omitted, are constructed in much the same manner as those named at pp. 124, 126 respectively for quick speeds and light loads, and those for heavier work. A slight but not material modification in some of the details is necessary.

The electric motor is proportioned in power to the load to be raised. Taking a hoist capable of raising 20 cwt. at the rate of

100 feet per minute, the motor should be about 7 B.HP., and should give about 80 ampères at 80 volts. The motor is placed at one end of the engine side-frame, and is attached to the bed-plate and connected with the driving-shaft of the hoist, either by spur or patent frictional gear. The latter is the most preferable arrangement, and is noiseless in working. This system of working is described at p. 124. By this plan there is only one working lever required, by which the lift may be started and stopped, and the weights lowered. The current is obtained from a convenient wire or conductor, either laid in a trench underground, or suspended overhead. The current first passes through a frame of resistance coils, and by means of a switch attached thereto, the requisite power is communicated to the motor. An extra switch is provided for starting and stopping the motor. The man has the fullest control of the machine, and can work it as readily as in the case of the steam hoists before described. When these hoisting engines are distributed in places at some distance apart, much advantage is attained by electric over steam power, principally owing to the condensation of steam in the pipes leading from the main boilers. The form of these electric hoists may be modified to suit special cases, the power can be adapted to most of the types of steam hoists already described.

CHAPTER II.

STEAM LIFTS FOR GOODS.

STEAM LIFTS for raising goods may be worked by any of the before-named steam hoists; the steam can be conveyed some distance from the boiler to work the same, as in the case of the cranes. The goods are either raised in a cage, or on a table or platform; the cage is suspended by a wire or hemp rope or a chain. It is guided at the sides by short rubbing guides attached to the top and bottom of the cage. The guide-bars are either L-iron, or cast-iron with planed V-faces. Part of the weight of the cage is taken by a counterbalance weight.

LIFT FOR 12 CWT.

The Cages are constructed with a L-iron frame at bottom and top, 3 inches by 3 inches by ½ inch; they are strongly braced together, the floor is of oak, 1½ inch thick, and the top and sides of pine, ¾ inch thick; rubbing guides, lined with gun-metal (in case of passenger lifts), are fixed at the top and bottom of the cage. Safety gear is provided to prevent accident in case the rope breaks (see p. 140); a suitable size for average cages is 5 feet by 4 feet by 6 feet 6 inches high inside dimension.

Guide-bars should either be cast-iron planed on the faces, or wrought T iron, not less than 3 inches by 3 inches by ⅝ inch, well fixed to timbers or stone templates built in the side walls. These bars should be erected perfectly vertical, and dead plumb all ways, firmly bolted, and should be most carefully fixed at the joints, to prevent any movement or friction at these points.

Counter-balances should be provided, taking part of the weight of the cage. They should be flat in shape, about 18 inches to 20 inches wide and 4 inches thick, and have planed grooves at the sides, and

should work in 2-inch L-iron guides; these guides must also be fixed vertically, and the edges carefully filed to prevent undue friction and noise in working.

Ropes, either of hemp or leather, and in some cases chains, are used to lift the cages. The rope for the balance may either be of hemp, wire, or leather, or in some cases also a chain may be used. The ropes work over a top wheel, which should be of a large size, say, 2 feet in diameter, turned in the groove to save friction and injury to the rope; the wheel should be keyed to a shaft working in gun-metal bearings. In some cases the lifting rope is coiled direct on to the barrel, when this is placed immediately over the cage of the lift. The rope-wheel for the counter-balance is made of a diameter equal to the distance between the centre of the cage and the centre of the working edge of the L-iron guide-bars.

Working Gear.—The lifts are operated from the inside of the cage either by ropes or rods, giving motion, by means of levers and links, to the valves of the hoisting engines or the driving gear of the barrel.

The position of the engine and the gear must depend upon circumstances; it is not material to its successful working; a position about midway on the floors is convenient, or it may be placed near the top or bottom of the building.

Safety Gear (*Drawing No.* 69).—This should be fixed on the top of the cage of every lift, to prevent accident in case of fracture of the rope or chain. The following is a description of a plan designed by and worked for many years under the superintendence of the Author.

The guide-bars for the cage in this case are fixed on two timbers, wrought on the two sides and faces; these timbers must be erected perfectly vertical, and made true on all sides. At the top of the cage a shaft is fixed, having one eccentric or cam wheel keyed on at each end of same. On the other sides of the timbers two toothed or serrated racks are fixed; the lifting rope is attached to the top of this apparatus, and by means of an arrangement of levers, &c., directly it breaks, the cams are thrown into gear, and jamb the timbers on each side, and so stop the fall of the cage. When the lift is running at a speed of, say, 150 feet per minute, the fall of the cage at a fracture of the rope does not exceed 3 inches. Many plans have been tried and failed, and, after careful study of such failures, the Author introduced the above, and he is happy to say it

has worked both safely and successfully. Particular attention is drawn to this most important subject, as many very serious accidents have occurred, especially in the cotton districts, where lifts are so largely used. Some years since, the Author made a careful inquiry and personal examination into all that had been done in applying safety apparatus to lifts, and in Manchester more especially, by the courtesy of several of the leading warehouse proprietors, he was allowed to examine their various apparatus. In many cases it was of the most complicated kind, and when he endeavoured to bring it it into action, it *failed*. As in very few of these places they had experienced any serious accidents—chiefly owing to the good quality of the lifts, and the great care given to the ropes—while not making them indifferent to any good apparatus that might be offered them, they had relied upon what they had been accustomed to use. Since this time many very good apparatus have been brought out and successfully applied, and the Author can state, from personal experience, that many very serious accidents have been avoided by their use. He is of opinion that the Legislature should make it compulsory for all users of lifts to have safety gear attached.

Steam lifts are used for a variety of purposes, but with the exception of a variation in their sizes and strengths, to suit the loads they have to deal with, the general design need not differ from that above described; there are, however, some special applications that deserve some notice.

Endless Chain Lift for Passengers.

The first application of this kind of lift was about forty years since at the General Post Office, St. Martin's-le-Grand. Lifts of this kind have been adopted elsewhere; but although they differ in slight details, the general principle remains the same. A suitable way of constructing lifts of this kind is in the following manner:—

The lift consists of two endless steel chains passing over top and bottom specially-made pulleys. To these chains are attached at certain intervals the tables or platforms to carry the passengers; as each of these tables comes level with the various floors, the person wishing to ascend or descend has only to step on or off the table, and

be carried to any floor he wishes, having then only to step out when the table is about level with the floor where he wants to alight. The speed is rather slow, to prevent accident; they are not, however, to be recommended where it is convenient to apply any other kind of lift. The links of the chains should be made of steel, with drilled holes, and turned steel pins carefully fitted. The guide-bars should be cast iron, planed, and erected perfectly vertical. The machinery for working is usually a small horizontal engine, this may either be worked by steam boiler, or by a gas engine. This latter is somewhat more costly in daily working; but as there is no dirt or dust, no skilled attendant required, and the rate for insurance not being affected, in many cases its use may be recommended.

This class of machinery requires the most careful examination from time to time. Owing to the number of moving parts, and the strains to which they are exposed, the work should be of the highest class, and the material of the best description.

Examination of Lifts.—Lifts of every description should be examined at certain fixed periods by competent people; it is not only unsafe to neglect this precaution, but in the end proves false economy, without taking into account the serious risks that may occur to human life. Much loss may be saved by repairs being made in proper time. Cheap machinery, especially of this class, is to be avoided; well-designed and properly-executed work will always prove not only the most effective, but the most economical. When it is possible to avoid it, lifts suspended from a rope or chain should not be used for passengers.

Lifts for Raising Ore at Blast Furnaces.

One very notable one was erected some years since by Messrs. Samuelson & Co., at their furnaces at Middlesborough. It is of the direct-acting class, very safe in working, but of necessity rather costly in construction, and not quite so economically worked as the ordinary hoists, owing to the unavoidable condensation of the steam in the cylinders. The average weight of a loaded truck is 14 tons, the height lifted is 40 feet. The hoist consists of an inverted steam cylinder, 38 inches in diameter, by 40-feet stroke, made in several

lengths, flanged and bolted together; the piston-rod is connected to the crosshead of the cage. The load is raised by the direct action of steam on the piston and rod, and is lowered by exhausting the steam, which is passed to the other side of the piston to keep it warm. The actual exhaust takes place on the next upward stroke. The simplicity of action and safety well compensate for any want of economy in the steam used in daily working. The Author believes this hoist is unique of its kind, and is not aware of any other having been erected in this country. This type of lift would be suitable for raising goods, when the height does not exceed 15 to 20 feet, especially in cases where it is not necessary to sink the steam cylinder in a well in the ground.

Various Lifts.—There are various other kinds of lifts, both for passengers and goods, in occasional use; but as many of them cannot, with due regard to safety, be recommended, it is not necessary here to enter into detail as to same.

Electric Power Lifting Apparatus for Goods and Passengers.

These lifts, as far as their general construction is concerned, are much the same as for steam lifts described at p. 139. The cages, guide-bars, counter-balances, ropes for lifting, &c., require but little if any modification. The cages are raised by two wire ropes, which wind upon a barrel about 18 inches diameter; the counter-balance may either be run over a grooved pulley or wound off on the other side of each end of the drum, over two grooved wheels to the balance. The electric motor to work the lift is preferably placed at the top of the lift hole. If, however, circumstances render it more convenient, it may be situated at the bottom; the position is not of any material consequence, provided it is kept free from dirt and dust. For a 10-cwt. lift, to work at a speed of about 100 feet per minute, the motor should give about 30 ampères at 80 volts; the current is obtained from any convenient wire or conductor. It is first passed through a frame of resistance coils, from which, by means of a switch attached to it, the requisite amount of power may be communicated to the motor through another switch, which pro-

vides the means of starting and stopping. A special arrangement is made for lowering. The power applied, and the speed of raising the load, can be adjusted as desired. As a rule, lifts of this kind, especially for passengers, should not exceed 120 feet per minute. For the latter purpose, two wire ropes should always be employed, coiling on to drums not less than 18 inches diameter. The counterbalance should also be worked by a wire rope passing over an 18-inch diameter wheel, turned in the groove as described above. A safety apparatus should be attached to the cage, constructed in the manner described at p. 140.

Electric Power, as applied to lifts, is most convenient in places where it can be easily obtained; when this is from the cable of a public supply company, it is available by day and night. No special attendant need be kept on the spot, as it can be easily and readily started by any one who has received some previous instruction. In the case of other power lifts, except the self-acting hydraulic power, attendants are required to attend to the engines and boilers. There are many cases where they may be employed with much advantage, more especially for light loads and where the lifts are placed in isolated positions. The same remarks as those made in reference to the electric cranes and hoists equally apply in this instance.

CHAPTER III.

STEAM TRAVELLERS, HOISTS, CARRIERS AND ELEVATORS.

Steam Travellers.

Travellers for use in workshops and yards are constructed in the following manner. The girders should be made of wrought iron, and either be lattice or plate girders; the end carriages should also be girders of wrought iron, hung at each side on two large cast-iron wheels which run on the rails of the gantry. These wheels should be provided with double flanges, and be well spread as to the distance between the centres, to give a good base, and so prevent twisting. On the top of these girders, light rails are fixed for the traveller to work on. The gear for lifting should be fixed to wrought-iron frames hung on four flanged wheels, as before described; single and double purchase should be provided to suit the various loads, this apparatus is made in much the same manner as a crab.

There are several ways of working the travellers: First, by shafting; in this case a long square shaft runs down one side of the gantry, on which a wheel with a square hole slides, and by means of gear moves the traveller as desired: the shaft is driven by the general engine. Second, by steam boiler working a steam crab; this latter plan is most suitable for outdoor work, especially where the travellers are placed at some distance from each other, and must be worked quite independently. The man to work the apparatus in this case stands upon a platform attached to the girders; in the former case he may stand upon the floor or on the girders of the traveller. Third, by endless ropes driven from the main shafting of the place; this gear has lately come very much into use, and answers its purpose admirably.

25-Ton Steam Traveller.

This machine is suitable for use in large engineering works. For inside work, a gantry should be prepared by fixing side tram rails at a suitable height on cast-iron brackets built into the walls, or attached to the side girders of the shop. For outside work, an independent gantry has usually to be erected, either constructed of timber or ironwork, according to convenience. Iron, although rather dearer as to first cost, is, on account of its lasting power, perhaps the most economical in the end.

The traveller is 42 feet span, and represents an average width of shop; for longer spans than this, and to lift 25 tons, the girders become too heavy. The cross girders may either be made in the box form or constructed as lattice girders, and made of proportionate depth and scantling. The girders at each end are framed into longitudinal girders or end frames, about 8 feet long and 1 foot 6 inches deep; they are supported at each side on two double-flanged tram wheels, 20 inches diameter.

Motion for Lifting.—This consists of two chain barrels, one for heavy and one for light loads; either chain can be readily put in and out of gear. The barrels are made of sufficient diameter to lift the whole height without overlapping. Two speeds are provided for each chain-barrel. All the shafts and spindles are of steel. The longitudinal motion is worked by shafting and spur gearing; it is geared at each end to the driving axle, to ensure that the traveller moves parallel to the rails. All the motions are put in and out of gear by belts, under the control of the man working the traveller. The motions are all steel geared. The traveller is moved by endless fast-running cotton ropes, and is operated in all its movements by one man, who is provided with a platform suspended below the girders. The lifting chains pass round movable sheaves. The traversing motion is much the same as usual; it also is operated by the man from the platform.

40-Ton Steam Traveller.

Travellers ot this construction, and worked in the manner described, are principally suitable for working in yards and open places, such as docks, harbour works, and like purposes. The traveller is run upon a gantry, which may be constructed in the same manner as described on p. 146. The transverse girders should be in the box form, connected at each end by others, also in the box form, these latter being hung upon two flanged wheels as before. The span of the traveller is about 42 feet, or it may be made up to 50 feet if required. The height of lift is 16 feet. The machinery is placed on top of the girders, and consists of an iron frame or carriage, mounted on four flanged wheels, running on rails attached to the top of the girders. On this carriage a vertical steam boiler, 4 feet diameter by 8 feet high, is attached, and a lifting motion worked by two steam cylinders, 14 inches diameter and 2 feet 6 inches stroke. All the motions for lifting and travelling horizontally and transversely are given by the engine; the lifting gear is fitted with single and double lifting power, to give facility for raising either the maximum or lighter loads. The travelling motion is put in to gear by friction cones; this relieves the machine from the shocks to which it is liable when clutch gear of the ordinary kind is employed. The author introduced this system for use in steam cranes and hoists many years since. It has always worked in a perfectly satisfactory manner. For operating the longitudinal movement of the traveller, a square shaft is provided, fixed outside one of the girders; the bearings are of the trip kind; the driving-wheel on the hoisting engine slides on the shaft. At the end of the shaft a train of wheels is provided, which gear into the tram wheel motion on either side. The lifting chain is attached to the barrel of the hoist, and passes under a movable pulley, and is made fast under the frame of the hoist. The sides of the crab should be made of wrought-iron plates, which are strengthened with L-iron and made in the same manner as described for cranes at p. 108.

Modification of the Traveller.—The boiler and machinery may be made a fixture at one end, and a small traveller truck can be

employed to carry the lifting block. By this plan the girders are relieved from the weight of the travelling boiler and machinery. These travellers, as before stated, are for use in open places; they are not so suitable when placed under cover, on account of the nuisance arising from smoke and waste steam.

Travellers of this kind are often used on "Goliath" frames, as described at p. 165, more especially in places where a side gantry cannot be used. In this case legs are attached at each end to the girders and side frames, mounted on two flanged wheels on each side. The frames and girders in some cases are made of timber.

25-Ton Electric Power Traveller.

This is an illustration of the adoption of electric power to drive lifting gear of travellers; the author believes Messrs. Willans and Robinson, Limited, of Thames Ditton, Surrey, were one of the first firms to carry it into practical use, and to work it daily for lifting and moving weights of 8 tons up to a maximum of 25 tons. These cranes are used both in their erecting shops as well as in the foundry department. They both work admirably, not a single hitch has taken place since they were started. By the courtesy of the firm, the author has been permitted to examine the travellers, and having been kindly furnished with data, and received their help, he is enabled to give more particularly a description of the larger traveller which is used in the erecting shop.

This traveller, and gantry on which it runs, is made of wrought-iron, except some part of the gear, which is of steel.

The transverse or travelling girders of the traveller are of the I form, 36 inches deep at the ends, and 18 inches at the centre, the width of the flanges being 12 inches, and ½ inch thick; the span across the gantry is 39 feet. The two girders are placed at a distance of about 5 feet centre to centre, and are housed into end girders of the box-section; these are mounted upon double flanged tram-wheels, placed at 8 feet 10 inches centre to centre of the spindles; it will be seen this renders the movement of the traveller along the gantry perfectly steady. The traverser runs in the usual manner on the top flanges of the main girders; it is operated to and

fro by an endless rope; the gear consists of spur and bevel wheels, with the addition of worm and worm-wheel gear for lifting. The lifting chain is 1¼ inch best short link crane chain, and is fitted with a return block; it is coiled on a chain-barrel or drum, and is capable of raising a load of 25-tons to a clear height of 25 feet above the floor of the shop. The wheels to move the traveller longitudinally are spur and bevel gear; one tram wheel at each side is connected to a transverse shaft, which enables the traveller to advance regularly on the gantry.

The Electric Motor giving the power to operate all the motions of the gear of the traveller is placed at one end of the transverse girders in a convenient position to the hand of the man working it, who stands upon a platform suspended below the transverse girders. The current is obtained by a wire or conductor stretched the entire length of the shop, and placed a short distance above the traveller girders; contact is made by brushes which slide along the wire. The return-wire or conductor is placed at the other side of the gantry. When starting, the armature current is first passed through resistance coils of iron wire, a switch being provided to give the necessary variation of speed, and for starting, an extra switch is provided to make and break this circuit. The magnets of the motor are kept constantly excited, but can be switched off, if desired, for repairs. The object of this arrangement is to prevent the motor armature being short circuited, by putting the armature current on before the magnets are excited. The motor is about 8 B.HP., and uses a current of about 90 ampères at 80 volts; this is made by the Electric Construction Corporation, Limited, and is wound as a shunt machine. The armature has no outside bearing, but is wound on a sleeve, as with all Messrs. W. and R.'s motors, and overhung on the rope-pulley shaft. Any of these armatures can be taken off one crane and put on to another, all shafts being alike. A strap is taken from the armature-shaft which gives motion to the spindles and shafts of the longitudinal gear, and an endless rope works the lifting gear and transverse gear; a series of rods and levers, capable of adjustment by the hand of the operator, is provided, and the motions are worked by open and crossed belts.

The speed of lifting, also moving, the traveller and its load in each direction is about the same as in steam travellers, and is

operated with the greatest ease. The cost of working is less than by steam-power, more especially where, as in this instance, the main boilers are placed some distance from the traveller.

Foundry Steam Cranes and Travellers.

A very nice arrangement for steam cranes for foundry work is constructed in the following manner.

The jibs are made of wrought iron, and are worked on fixed bases and heads. The gear to work them is fixed on top of the jibs for the racking out motion, and on the post for the lifting motion. A longitudinal shaft runs down on one or both sides of the foundry, and by means of an arrangement of levers and gear, four cranes can be worked by one man situated on a platform midway in the foundry, and near the wall. They are more economical as to the expense of working than hydraulic cranes, and are much preferred by many founders to ordinary travellers for this kind of work.

For small heights and weights, cranes may be worked by direct-acting steam cylinders, much in the same manner as those described for hydraulic power; the cylinders and all the pipes must be clothed, and care taken to prevent condensation.

Foundry cranes are also constructed the same as the above as regards the jib, the means of working being a steam hoist fixed on the post of jib, or near to it. In this case a man is required for each crane, and the cost of working is rather more than the arrangement just described.

Endless Chain Hoists (Drawing No. 70).

These apparatus are very suitable for raising casks, bales of goods, &c., where the action is required to be continuous and can be made self-feeding; for raising casks of beer, &c., it is the most rapid system in use; these hoists consist of two chains, placed a short distance apart, working on octagon drums situated at the highest and lowest points. At suitable distances "horns," or angle grip brackets, are fixed to carry the cask, &c.; the chains are kept in their position by stays, and work at the sides upon cast-iron friction rollers; the

shafts of the octagon drums, &c., work in two cast-iron side frames. At the lower part the goods slide down, or roll off, an inclined plane to the hoist; in the case of casks, as the "horns" come round, they are carried up, and by means of rails placed on the upper floors and laid in an inclined position *from* the machine they are run away. When other goods are to be raised, such as small cases, they are carried forward by an endless band, and by means of suitable gear two arms move the package on to small tables, which are fixed to the "horns" above described; as the goods arrive at the top they are either taken off by hand or by gear of some simple character.

These machines can either be fixed vertically or in an inclined position, and be driven from any convenient shafting or by a separate engine. The speed should be rather slow, to allow time for the goods to be put on and taken off the machine. The links of the chains may be of wrought iron fitted with turned steel pins, the holes should be case-hardened, and the lengths of links centre to centre made exact. These links should be made as described at p. 153.

Endless Band Conveyors for Grain, &c. (Drawing No. 74).

A very economical way of moving grain or goods of like kind is by means of an endless band; it may be made of woollen material, india-rubber or canvas. It works on two rollers equal to the width of the band; wood bearing-rollers are fixed at intervals to support the same; means of tightening the band are attached at one or both ends of the apparatus. When cases of goods have to be moved horizontally, the chain in this case is formed of two long-link iron chains, with narrow boards attached to the centre of each of the links. These boards should be made of beech. The band or chain is driven by a belt, and by means of a friction clutch can be made to throw itself out of gear in case of any obstruction to the goods when travelling on the band. The bands may be made 200 to 400 feet in length and above; they work perfectly if well designed and properly constructed. It is a rapid and economical way of moving grain, &c., and takes very little power to work it. These bands are largely used by the Author for removing spent grains from mash tuns at breweries. Some few of the details have to be specially arranged for this pur-

pose, as well as the addition of apparatus to clean the surface of the band; the speed has to be carefully regulated, as it is found in practice wet grains cannot be carried away readily unless this has attention. These bands work with less expenditure of power than the screws described below, which are occasionally employed for this purpose.

Woollen bands of the above kind are also used for transferring or pumping liquids from one vessel to another. The speed in this case requires very careful adjustment, and varies with the kind of liquid. It is a very ingenious contrivance, and effective in action.

Screws, or Creepers, for Grain, Flour, Charcoal, &c. (Drawing No. 75).

These apparatus are for the purpose of moving such goods in a horizontal direction; they consist of a central shaft of cast iron, with a helical flange cast on, to which a wrought-iron bladed screw is attached; the diameter at the periphery of the screw varies from 6 inches to 24 inches. The screw works in a wrought or cast-iron casing, made trough shaped, provided with top flanges and a cover; at one end the driving gear is applied, and the other is provided with a small relief door to let the goods out in case of any stoppage. The shaft of the screw should be fitted with couplings to allow the same to be disconnected easily. The speed of the belt for malt, corn, &c., should be about 250 feet per minute. The details of this apparatus vary according to the kind of goods to be moved.

Elevators, or "Jacobs" (Drawing No. 76).

These apparatus are well known for the purpose of raising corn, barley, malt, and other grain, as well as charcoal, cement, &c.

For Corn, Malt, &c., the endless band is made of leather, with tin buckets fixed to it at from 15 inches to 18 inches apart. The top and bottom pulleys on which the band works are enclosed in a casing of wood or iron, provided with suitable bearings lined with gun-metal. At the bottom of the casing an arrangement is made for

the purpose of tightening the band; a vent-valve is placed at the top to prevent firing; should an explosion take place, the valve opens and gives immediate relief. The pulleys should be proportioned according to the size of the buckets; 14 inches diameter should be the minimum size. The buckets must not be placed too close together, or they will not delivor easily. The speed should be about 200 feet per minute at thè band.

For Coals, Spent Hops, and other Heavy Goods, the elevator is formed by two side chains, with iron buckets attached; the two chains are kept apart by wrought-iron stays, and work over cast-iron octagon shaped drums, placed at the top and bottom of the elevator. They are also used to carry up the contents of excavations, ballast, sand and water, &c. They are self-feeding and delivering, and require very little personal attention. The chains must be made in the same way as those described for the endless lifts, see p. 150; they should be made in a mould, and carefully drilled by special apparatus to ensure that each set of links of the chain are the same length on each side. This is for the purpose of avoiding unequal strains.

In some of the large breweries these elevators are from 50 feet to 60 feet high; any inequality in the lengths of the links in such cases would cause an accident and stoppage to this part of the plant —often a very serious matter, and involving heavy losses. This is a case where the work should be of the highest class, and first cost not so much considered as good sound work.

CHAPTER IV.

GENERAL REMARKS ON STEAM LIFTING MACHINERY.

STEAM power can be applied in many cases where hydraulic power is not admissible. The cost of working is in favour of steam, both as to coals, wear and tear, &c.; also in the first cost, which is much less, thus reducing the interest on capital and sinking fund, all of which must be taken into consideration in forming estimates to be of any practical service.

Where the insurance offices will not allow any fire, a gas engine can be used with much advantage; in some cases gas boilers have been used, but the advantage of economy certainly is on the side of the gas engines. In many cases the convenience attending their use is so great that the cost of gas is a matter of very little moment.

THE COST OF UNLOADING GOODS by steam cranes may be taken at 5*d.* to 6*d.* per ton; this includes all expenses, wear and tear, interest on capital, and depreciation, &c., of plant. It must be borne in mind, the number of cranes must not exceed the trade of the place, or the above cost will be materially increased by the loss of dead capital. The cost of unloading where only one or two cranes are employed will exceed the above amount. The positions also of fixed cranes should have very careful attention to suit them to the special requirements of the particular class of business to be carried on at the place.

Cost of working Steam Cranes compared with Hand Labour.—The cost of working five warehouse cranes by hand labour, at one of the large London wharves, is £5 17*s.* 4*d.* per day. The cost of working five warehouse steam cranes, including all expenses, labour, coal, wear and tear, interest and depreciation; is 30*s.* per day; the cost of coal per week is about 29*s.*

Steam Pipes.—All pipes must be placed at least 6 inches clear of

the timbers of a building, and where they pass through floor boards an iron plate must be fixed on them to protect them from heat. The same applies to pipes passing through any roof, partition, or timber construction of any kind; steam would otherwise desiccate the wood, and render it short and more easily fired. It is also necessary to carry out such an arrangement on account of the regulations of the fire offices. It is advisable to have an interview with the surveyor to the offices, to settle what special provisions they require, in order to include the work under the contract, and save making expensive alterations after the work has been completed.

Pipes placed in trenches should be laid to fall to the condense boxes; these should not be further apart than 60 to 80 feet. It is almost needless to say steam pipes must be coated with non-conducting composition or felted, and must be perfectly well protected from the weather. The trenches should be formed in brickwork, and of sufficient capacity to readily get at the joint of pipes, valves, and other connections.

Condense pipes, fitted with petcocks, should be fixed in all steam cylinders, and means should also be provided to drain the steam and exhaust pipes, when the machines have been standing any time, to avoid risk from frost.

Cast-Iron Pipes should be flanged and faced, the holes drilled and be well provided with expansion joints. The best kind are hollow copper discs; these do not rust up and become useless in the same way as the old kind of sliding joints. All bends should be easy, no square elbows used, and where T-pieces join the main pipe, the junction should be curved to allow the steam to flow freely. At various points on the top of the main, air-cocks should be provided, which should be opened every day at first starting to discharge the air in the entire system of the pipes; the petcocks at the bottom of the pipes should also be opened to let out condense water and allow the steam free passage.

Wrought-Iron Pipes should be flanged in places, and be provided with means to allow of easy disconnection and also to make repairs expeditiously in case of accident. For this purpose the pipes should have valves fitted, to shut off the steam at various points. The same remarks as for cast-iron pipes, as to flanges, &c., apply, and also as to the expansion joints.

Cocks.—At the cranes and hoists, solid bottom cocks are better than valves, as they allow the steam to be instantly shut off in case of emergency; the spanners should always be fastened by a screw, and should be chained to the cock.

Blow-off Pipes.—These should be fitted with a cast-iron cup and hood to take the condense water, and thus prevent any water falling on the men or on the wharf, a small pipe is carried from the bottom of the cup to the base of the crane to take away the waste water.

The Author (as before mentioned) has carried steam pipes long distances, in some instances 500 feet to 600 feet and upwards from the boilers, and, where proper means are taken to protect them from the weather, and the above-named arrangements are made, very small loss of pressure takes place.

Steam Cranes, as well as other apparatus worked by steam are not affected in the most severe frost, and in this way have an advantage over hydraulic cranes, the pipes of which are occasionally frozen in severe weather.

At large wharves and other places, where the work is nearly constant, only one man should work each crane; it is advisable, however, to have men in reserve in case of illness or absence. This man should be made responsible for oiling and lubricating all parts, and keeping the crane and machinery clean. Good wages should be paid to competent men of this class, and encouragement given them, in the shape of small advances on their wages from time to time, when they do their work well and safely. It is a serious mistake to employ incompetent or careless men for this sort of work, as, in the event of an accident occurring through their negligence or want of knowledge, heavy losses may take place, besides the possible risk to limb and life.

PART IV.

HAND POWER LIFTING MACHINERY.

CHAPTER I.

WHARF CRANES.

7-Ton Hand Power Wharf Crane.—The best form of crane for a wharf or quay, railway yard or depôt, is constructed in the manner described below.

The posts are either cast or wrought iron fixed in a cast-iron bed-plate, also in a footstep in the masonry of a well, where they are firmly keyed, or they may be held in a boss in the base-plate in the same manner as described for steam and hydraulic cranes; in this case no well is necessary under the crane, but a larger and heavier brickwork foundation is requisite, as well as more powerful holding bolts and plates.

The top part of the post is turned. The side frames consist of two cast or wrought iron cheeks, with top and bottom distance pieces or frames bored out at centre, to fit the turned parts of the post. The bed-plate is cast iron, strongly bolted to the masonry; it has a circular rack, or wheel, at the top, and a conical race for the guide wheels to work on. The post is turned at the part where it passes through the centre boss in the base-plate, and is keyed to it.

The jib is of wrought iron; it is made in the same way as described for steam cranes (see p. 108), or it may be of oak, fitted with top and bottom cast-iron shoes. At the top is a grooved chain pulley, 16 to 18 inches in diameter, and at the base a conical friction pulley, which rolls on the race fixed to the base-plate. The pin on which the wheel runs should be turned, and the boss bushed

with gun-metal. Two wrought-iron tie rods, with bored eyes at each end, are attached to the jib-head and the side frames, provided with stays and rollers to keep them apart and to take the weight of the chain when it is slack.

The gear is either double or treble purchase, the barrel placed as low as possible, and of sufficient length to coil, say, 25 to 30 feet of chain without any overlap. The steering gear is at the back of the crane; it consists of a pair of bevel wheels, one being fitted to a horizontal shaft, to which a winch handle is attached, and the other to a vertical spindle running through bearings in a column, also having at the lower end a spur pinion which gears into the circular rack on the base-plate.

The brake wheel is usually cast on the side of the large spur wheel, the strap should be wrought iron lined with either oak or beech. The brake should *never* be applied on the teeth of the spur wheel, as it is a very dangerous practice, and serious accidents have happened through this cause.

For raising heavy weights, a movable pulley attached to the jib-head is used; but when lighter weights are required, this is dispensed with.

All wheels should be bored in the boss, and all shafts turned. It is advisable also to tip the tops of the teeth of the wheels. The pinions should have side shrouds, and not less than twelve teeth. The radius of the winch handles should not be more than 18 inches —the usual radius is 16 inches; and the height of the centre of the shaft not more than 3 feet 3 inches from where the men stand who work the crane.

The width of the bearings should be equal to at least $2\frac{1}{2}$ to 3 times the diameter of the shaft.

It is advisable to cover over the working gear by a hood, made of sheet iron; this protects the machinery and also acts as a shelter for the men in wet weather.

The chains should be of ample strength, and not worked to more than half the proof strain. It is to be further observed, when heavy goods are lowered by a brake, care should be taken not to subject the crane to heavy shocks by suddenly putting on the brake. A notice to this effect should be posted on the crane; it may be the means of avoiding accidents and consequent loss.

20-Ton Hand Power Wharf Crane.

Hand power cranes for wharves, quays, railway depôts, &c., for raising loads up to 20 tons, are constructed with wrought framing, jibs, and ties; the side frames are made of wrought-iron plates, about $\frac{9}{16}$ inch thick, having L iron riveted round the outer edges; the bosses which form the bearings for the shafts and spindles are bushed with gun-metal, and are riveted to the exterior of the frames. The jib is made in the form of two riveted girders, which are well braced and riveted together; the lower part is made the same width as the distance between the inside of the side frames, and at the top part it is wide enough to carry a grooved chain pulley 22 inches diameter, which runs on a turned steel pin $2\frac{1}{2}$ inches diameter, passing through each side plate or flange of the jib. At this point side plates, $\frac{3}{4}$ inch thick and about 3 feet long, are riveted to strengthen the plates, and at the lower part plates are also riveted about $\frac{7}{8}$ inch thick and 4 feet long. The jib is attached to the side frames by a turned steel bolt 3 inches diameter, which also passes through each of the frames. Two wrought-iron tie rods, $2\frac{1}{4}$ inches diameter, are attached by eyes at the upper part to the pin of the chain-wheel, and to the top portion of the side frames at the lower part. Two stays or rollers turning in carriages are fastened to the top of the tie rods for the purpose of carrying the chain when slack. The winch spindle is placed at the front part of the side frames, on which bearings are provided, and by means of two pairs of spur-wheels motion is given to the chain barrel, which is placed near the top of the side frames at the back part. The post is of wrought iron, and is stepped into the bored boss of a cast-iron base-plate, and to which it is keyed. The two side frames are held together by a cross-head or distance frame at the top, which is provided with a bored boss fitting the top of the crane post. At the base of the side frames a cast-iron distance frame is bolted between them, having a bored boss fitting the turned part of the post at this point; the boss of the plate bears on a collar on the post. A cast-iron base-plate is bolted to the foundation of the crane; it is provided with a turned curb or race, round which the crane travels, the lower part

of the jib being fitted with a conical friction roller about 16 inches diameter. On the inner part of the curb a circular rack is provided. The steering gear is placed at the back part of the crane, and is worked by a separate winch-handle. A brake-wheel, strap, and lever are also provided, as well as clutch gear and levers for operating the two motions, with which the crane is fitted, for working the maximum or lighter loads. The chain is attached to the head of the jib, and passes under a movable pulley block to the top wheel, and from thence to the barrel on which it is coiled. The radius of the crane is made 20 to 25 feet to suit the work to be done. The approximate weight of all the crane complete is about 20 to 21 tons.

FOUNDATIONS.—These should be of brickwork, resting on a good concrete base, with a Yorkshire base stone at the top, not less than 12 inches thick. All the work should be done in Portland cement, and where the soil is of a soft nature, piles should be driven, cut off level at the top, and then planked over; on this platform the concrete base should rest. It must be borne in mind, the first cost of a good foundation will be more than saved by the decreased wear and tear of the crane in working.

PORTABLE CRANES.

The general form of this class of crane, in the details of the working gear and arrangement of the parts, is the same as above, except that the post should be wrought iron, and the cast-iron base-plate extended and fixed to a trolly or truck running on four wheels. The gauge of the wheels is usually made 4 feet 8½ inches, to run upon a public railway if required, or it may be made to any gauge to suit the special case; the distance from centre to centre of the wheels longitudinally should be well spread, to give a good base and thus ensure steady working. The frame should be made of wrought-iron girders, well riveted together, and the base-plate of the crane bolted directly on the top; the side frames are made with long tails, to carry a counter balance box, which is capable of adjustment to suit the varying loads to be raised. In addition to the counterbalance, the wheels must be clamped to the rails when lifting a load; this is dispensed with in the case of cranes used for railway

work, as the trolly or truck on which the machine is placed, is made of sufficient length in conjunction with the counter-weight, to keep it steady during the time of taking a lift.

Wrought-Iron Jibs in both the fixed and portable cranes are preferable to wood, more especially in hot or wet countries; the wood is liable to decay, and rots or shrinks in the cast-iron sockets. The radius of the jib can be made adjustable, suitable to the various conditions of work; this is not, however, usually done, unless special instructions are given. In ordering or specifying, this should be expressly stated. It is not, however, desirable to have this done unless the work requires it, as the cranes do not work quite so steadily as when the jibs are of a fixed radius.

Derrick Cranes.

These cranes are mostly constructed of timber; they are made to take apart easily, and can be readily transported from place to place; they are very suitable for use for temporary work, and either for light or heavy weights. They are easily and quickly taken apart when required to move them to another spot. The working gear is much the same as in the ordinary crane; the radius of the jib is adjustable; by means of a chain running over pulley blocks they can be fixed at a level above the top of a building during construction, to haul up the material; they are usually in this case fitted to work by hand, steam, or hydraulic power. The gear is fixed to a bed plate or frame, and bolted complete to the post; much care is necessary to ensure this being quite true, to avoid undue strain upon any of the parts. The timbers at the base in any case must be well spread, and either be loaded or strongly bolted to the ground or platform on which it rests. The best material to use in construction is oak, but in most cases they are made of fir, on account of portability and economy as to the first cost. All the junctions of the various parts are made by cast iron sockets, to which the ends of the timbers are fitted; the timber should be kept well painted, to preserve it from the action of the weather. The radius of the jibs depends upon the kind of work for which the crane is to be used. As a rule, they are not made less than 20 feet, and often as much as 45 feet. They are made in sizes to lift from 1 ton to about 7 tons.

Foundry Cranes.

The best kind are made with wrought-iron jibs fitted with two powers, one for raising light and one for heavy weights, and are also fitted with a racking-out motion, which is connected by rods, and gear to the part of the crane near the man who works it.

The post is made of two trough girders with angle irons on the inside. The jib or top member is formed of two girders of the same class, leaving a space for the chain to work between. There are two diagonal struts of the same section which are riveted to the post and jib. The working gear is of the usual kind; the racking-out motion is worked by a separate winch handle. The post works at the bottom in cast-iron steps firmly fixed on a stone base, and at the top part in a bearing fixed to the timbers of the roof, or in some instances to top girders or framing.

For foreign work it is advisable to construct these cranes of timber, as in case of fracture they can be more easily repaired, and, where suitable material is at hand, the timber parts can be made on the spot, and so save the cost of freight and carriage; all the parts can be connected by cast-iron sockets as described for derrick cranes. The cranes are usually made to raise loads of from 1 to 5 tons; for heavier weights than this, they must be specially constructed.

The gear in this case is self-contained in a cast-iron frame, and is bolted to the wood post of the crane.

Platform Cranes for Loading Carts, etc.

These are sometimes made of timber, with gear to work them as before, except that in most cases an endless chain, working on to a spocket wheel, is used to raise the load. In this instance all the working gear is placed at the top part of the crane, and the post is thus left clear at the bottom part.

Cast-iron steps bushed with gun metal are fixed at the top and bottom for the post to turn in. The pivots are made of cast iron provided with sockets to receive the timber.

In most cases this type of crane is made of wrought iron. They are more suitable in this form than when made of timber; the latter are only to be recommended for foreign countries and isolated places. The author recommends those made in iron where first cost is not an object, as the difference in expense is not large.

They are usually called "whip cranes," and are much used in goods' sheds and railway depôts to load and unload carts and wagons. All the working gear being fixed at the top of the house, much room is saved at the loading stage, and greater rapidity of working is obtained by this kind of gear.

Portable Factory Jib Cranes.

These are very suitable for use in an engineering works for raising and lowering goods in and out of the various machines. The crane jib is made in much the same way as an ordinary jib; the post is supported at the base on an iron frame hung upon two double flanged tram wheels; these are placed at least 6 or 7 feet centre to centre; they run upon one rail sunk level with the floor of the works. At the roof or ceiling two rails are provided, on which four flanged tram wheels run; these are attached to a top bar, the wheels being placed at the same distance, centre to centre, as the lower ones. When top girders are not available the rails may be attached to any framing placed at a sufficient height for the jib to swing under. The lifting crab motion is placed near the top of the post; it is worked by an endless chain, which reaches to the floor. The crane is moved by spur gear operated by a winch placed near the floor. The load can be picked up and the crane run on the rails direct to the machine into which it is desired to put the work, and in removing it from the machine, it can be deposited near the traveller, the sling being left on, and by means of which it can be picked up, run away, and deposited where desired.

There are several forms in which this useful machine can be made to suit any special circumstances; the author commends the crane to the attention of designers who are laying out new works, or making improvements to old ones. They are usually made in sizes to lift 20, 30, and 40 cwt., with a radius of 10 to 12 feet. The

height from the floor line is about 10 to 12 feet; this varies according to the place where the crane is to be fixed. The relative weights of the cranes are about 2, $2\frac{1}{2}$, and $3\frac{1}{2}$ tons.

2-Ton Hand-Power Wall Crane.

These cranes are useful for foundries or factories, when it is required to keep the floor clear of the crane post and its gear. A crane of this type is carried on a cast-iron plate, which is bolted to the walls of the place. A footstep is provided at the lower part, and a bearing at the upper, in which the jib turns. The post, jib, and strut are each formed by two trough steel girders, all well riveted together; the jib girders are placed horizontally and level at the top, and on the upper flange of which a traveller frame runs; this gives the means of racking the load in or out as required. The gear, consisting of two motions for lifting, as well as that for the racking motion, is placed on top of the jib girders, both being worked by endless chains reaching to the ground, and running over grooved pulleys. The radius of the jib is usually made 18 to 20 feet, or any length to suit the particular work. The racking-out range is about 14 feet. The cranes may be driven by endless rope, by means of an engine, in places where any power is conveniently near. These cranes are very useful in shifting moulding boxes and castings; four of them, two being placed on either wall, are sufficient to sweep the floor of a fair sized foundry, say 80 feet by 40 feet. All the area of the floor can, in this way, be utilized, no portion being required for fixing the cranes. This is not only a convenience, but a great consideration in many places, and is worthy the attention of designers when laying out new works.

"Goliath" Travellers.

This is a form of traveller made in nearly the same manner as those steam driven, as described at p. 148. They are of the type used in stoneyards and other places, where an overhead gantry cannot be provided; two rails are laid on timbers at the ground level, and on these the traveller moves. It is constructed with side

frames of a height to allow a lift sufficient for the particular case. The span is made of any width required, as a rule not more than 40 to 45 feet. The whole framing is generally made in timber; two A frames, well framed and strutted, are supported on long timber sills on either side, which are hung upon two double-flanged tram wheels, from 18 to 24 inches diameter. The distance between the centres of these wheels will depend upon the span and power of the traveller; as a rule they would not be nearer than 8 to 10 feet from centre to centre. At the top of the side, or A frames, cross girders of timber are fixed; they are trussed with wrought iron rods, attached to cast-iron boxes or frames at each end, passing under two cast-iron struts, placed so as to divide the timbers into three equal spaces. The lifting gear is usually placed at the top of these girders at one end, and at the top two rails are also attached, on which the traveller works. The gear does not differ from that described at p. 147. In some cases a steam boiler and engine power are attached; these are placed either at the base or top of the traveller.

"Goliath" made of Wrought Iron.

The same kind of apparatus is also constructed in wrought iron work. The side frames are made of L and plate iron, well braced and riveted together, and mounted on 18 to 24 inches diameter tram-wheels at the base, in the same manner as the last. The top girders are made in the lattice form, having rails fixed on their top flange for the traverser to run on. The girders must be well connected to the side frames, and, to stiffen them at their junction, within, angle brackets must be provided; they are made in a curved form, to be out of the way of the goods to be lifted.

The working gear may be placed on the girders, and endless chains, reaching to the ground, employed to raise the load. The weight to be raised, as well as the span and other circumstances, must decide the best plan to adopt.

As a general rule, when this machine is made in ironwork in the form described, it is not adopted for any large height or span; the height of the side frames would rarely exceed 9 to 10 feet, the span 25 to 30 feet at the maximum, and the load lifted 2 tons. When to

be used for heavy weights and larger spans, it must be made in the same manner as the Goliath carrying steam-crane, except that, as no crane has to be carried, the girder and frame can be made of much less strength. For use in foreign countries, those constructed of timber are to be preferred, because they can be framed locally, and from the timber obtainable in the district; the cost of freight is thus saved. The engineer in such a case is advised to send out full detail drawings, showing all the parts; the ironwork and all gear should be sent out from this country, together with duplicates of all the chief parts liable to wear or fracture.

These are useful machines to employ for unloading barges that are run into a dock or water-way, when they contain heavy loads; but for light loads they are not suitable.

Shear-Legs.

For raising a weight at one spot, where no swinging is required, the best plan is a tripod, formed by three baulks of timber or good sound poles. The lower ends are shod with iron, with a wrought-iron spike at the bottom of each, to prevent slipping or spreading out when lifting the weight. The top of each timber has a wrought-iron strap bolted to same; a bolt passes through all three legs, fitted with a strong shackle, to which the lifting chain is attached.

A crab motion may either be fixed to one of the legs or a separate crab may be used, placed in any convenient position. This kind of apparatus is very useful, especially for temporary purposes; it is both strong and portable, and can usually be constructed from the material to be found in most localities. Good sound scaffold poles, as free as possible from knots, are very suitable for the purpose; they should be nearly the same diameter at the top as at the bottom.

Shear-Legs with Racking-Out Movement.

These are suitable for loading and unloading boilers, and other heavy weights. When on a large scale, for very heavy loads, the

legs are made of wrought-iron, in the form of a tube; the bottom of each leg being attached to a powerful cast-iron base-plate by hinged joints. The back strut or stay is also made of wrought-iron and attached to a sliding plate working on a strong base-plate, and connected by a pin to the top of the two legs. The crab motion for lifting is of the usual kind, several powers being provided, and a separate set of gear to rack the legs in and out as required.

This apparatus is, as a rule, only used in a large boiler, ship, or Government yards, but the same type of construction may be made of wood; it is very useful for temporary works, and can be rigged up by any good carpenter and smith. In some instances steam hoists are employed to make these shear-legs.

Derrick, with Two Legs Framed.

For temporary work two legs are framed together, shod with iron at the bottom, standing upon a baulk of timber. Three guide-ropes keep the legs in position, and, by adjusting the cords, the load can be moved to any required spot. Where much work has to be done, and the derrick required for some period, the legs are fixed at the bottom to a frame hung on two or four wheels; this is not only more convenient for shifting the legs from point to point, but also gives facilities for taking up the load at one spot and depositing it at another. The legs in this case are moved by spur gear connected to one pair of the tram wheels. The power applied to lift the weights may either be hand-power by crab motion, or by a steam hoist fixed near the spot, the chain being led to a grooved pulley on the legs by suitable guide pulleys. Special arrangements are made to allow for the range of movement required for the particular case.

Single Derrick Pole.

A derrick is often made with a single scaffold pole, for use in temporary outdoor work; the pole should be shod at the foot, and capped with iron at the top as before, the lifting power may be a separate crab, or a motion attached to the lower part of the pole,

or a pair of blocks and falls may be used, fitted either with ropes or chains. Heavy weights may be raised by this simple apparatus, and for erecting work outdoors, in the hands of skilled men, they may be made a very useful appliance. The pole should have but little taper, and must be sound, and as free from knots as possible. There are various other kinds of derricks to suit special requirements; the author, however, thinks they need not be more fully described here, as, with the aid of the above details, many other forms can be devised by an intelligent man.

CHAPTER II.

WAREHOUSE CRANES.

THESE cranes are usually fixed outside warehouse walls. They are constructed in wrought-iron, in much the same manner as described for the steam and hydraulic systems, pp. 22, 126. The radius of the jib ranges from 8 or 9 feet to 25 feet, and in some cases above. For warehouse placed flush with the public street, the radius should be sufficient to reach over the pavement into the centre of a cart or wagon standing close to the kerb of the footway; it is usually found in this case that 9 to 10 feet is sufficient. When fixed to a warehouse of a wharf near the river front, they are made of sufficient radius to reach to the centre of a ship's hatchway; taking the average of such cases they must be made from 30 feet and upwards. In the latter instance, the cranes are so placed to unload goods from ships, and land them either at the wharf level or on to the floors of the warehouse; in this arrangement it is convenient to place the cranes at different levels; thus, supposing four cranes are sufficient for the work, two should be fixed at the top of the warehouses to land into any floor, and two with the foot of the post about 6 feet above the wharf level to land into the first floor.

The cranes are constructed with posts, jibs, ties, and struts of flat iron, with cast-iron distance pieces riveted between; the angle of the jib should be 45°; all the details are the same as described at p. 126. They are usually made to lift loads of 2 to 3 tons maximum; the former usually represents the heaviest weight to be raised into the warehouse. For storing wine, tea, and other goods, light cranes of a special construction are used; the loads do not exceed 6 to 8 cwt. The same special gear is used for operating the jibs as named for steam cranes. (See p. 127.)

Crane Motions.—The motion to work hand-cranes is constructed

in much the same manner as an ordinary crab, with a train of wheels giving two or three powers. The spindles for the wheels and chain barrel are carried in two cast-iron frames, which are bolted at their base to the floor of the warehouse, and at the upper part to the timbers of the floor above. All the bearings should be bushed with gun-metal, and be provided with caps to afford easy means of removal and adjustment of the spindle bearings. A winch handle is provided on one side, and on the other a fly-wheel with a handle attached to one of the arms, about 8 or 9 inches from the centre of the spindle. Clutches and levers are provided for throwing the various motions in and out of gear. A counter-balance motion is also provided to bring up the empty chain when the motions are thrown out of gear. Brake-gear is fitted to the cranes, the strap should be of wrought-iron $\frac{3}{16}$ inch thick, lined with beech blocks, and provided with a counter-balance to take the break off when required.

Crab Motions for 40 Cwt.

The cranes are sometimes worked by crabs; they are double and treble purchase gear; the most usual forms have two cast-iron side frames, with bored bosses for the shafts to work in. To ensure truth, the two frames should be bolted together and the holes bored out at the same time; all the holes should be bushed with hard gun-metal, and bored out for the spindles to work in; the width of the bearings should be at least equal to two diameters of the shaft.

The spindles and shafts should be turned, and the wheels bored out and keyed on the same with sunk keys; *flats* on the shafts do not make good work, and should never be used.

The barrel should be bored at each end, and keyed to the spindle. A ratchet wheel is cast on one end of the barrel, and the pall to work into it is connected by a pin to one of the side frames. The brake wheel may be cast on the side of the spur wheel; it should not be less than $1\frac{1}{4}$ inch thick, and from 2 to $2\frac{1}{2}$ inches wide. The strap should be wrought-iron $\frac{3}{16}$ inch thick, and the lever should have sufficient power for one man to hold $1\frac{1}{2}$ ton easily, in some instances the brake is held by the foot resting on a plate attached to the lever.

Where the crabs are for inside use, the brake-strap should be lined with wood. The side frames should be H section, and have four wrought-iron collared stays, to keep them the proper distance apart. These stays should be (for 40-cwt. crabs) $1\frac{1}{4}$ inch diameter. The feet of the side frames should be made wider than the sides, to ensure a good firm base, and should have a bolt-hole in each foot, to receive bolts 1 inch diameter to secure them to the floor or the foundation.

Much greater care should be given in the selection of crabs than is usually done, in consequence of which, and owing to the competition which exists, very imperfect apparatus are in the market, and often get used, and in too many instances serious accidents are the result. In purchasing a crab, or in specifying for one, whatever weight is required to be lifted, it should be stated that "*it must be lifted direct from the barrel,*" otherwise the purchaser will be told "it is never done except with the aid of blocks," and he will get a smaller and much less *valuable* apparatus. This partly accounts for the large difference in the prices of the less scrupulous makers.

Travellers for Heavy Goods.

The details of the girders and gantry will be the same as described for the steam travellers, p. 145, except that in small machines the girders are either made of rolled-iron joists, or of timbers trussed with iron rods. The traverser and gear is also the same. To raise or lower goods, endless chains from the top gear reach to the ground, and, by means of spocket wheels combined with worm wheel and spur gear working a barrel on which the lifting chain is coiled, the load is raised or lowered. Two motions are provided for light and heavy loads. The traverser is also operated by means of gear and an endless chain reaching to the ground. The traveller is moved on the gantry by means of a cross shaft, to which two of the flanged tram wheels are attached. A spocket wheel, with spur gear and an endless chain operates the same. This kind of traveller is suitable for loads to 8 or 10 tons. Heavier loads than 10 tons are seldom required to be lifted at works where hand-power travellers are employed.

In some cases the men stand on the girder to work it, and thus the floor is kept clear; this, however, only applies in the case of large travellers.

The gantries on which the travellers move are either constructed with timber posts and top sleepers to which rails are fixed, or the rails may rest on brackets or corbels projecting from the side walls of the building; this latter plan is to be preferred when the place can be specially prepared during the building.

Travellers for Light Goods.

For raising wine, or other goods, up to 25 or 30 cwt., two rolled joists are framed to wrought-iron end girders, or plates, hung on four flanged tram wheels running on turned pins. The traverser is a small frame running on four tram-wheels, as before, with a cross bar in the centre; to this is attached a pair of differential blocks, by which means the goods are raised or lowered. In some cases a worm and worm wheel work a barrel coiling the lifting chain. An endless chain working in a spocket wheel at the top which is keyed on the tram wheel shaft, moves the traveller as desired. There are many modifications of the above, but, as they are mostly for special purposes, need not be described.

Single Girder Traveller.—A very useful apparatus of this kind is constructed in the following manner:—A rolled iron joist or girder is carried the same distance as it is desired to run the traveller; this forms a gantry rail; the girder is suspended by stays, brackets, or hangers, at every 8 to 9 feet; they are riveted at the top flange of the girder. At the lower flange a runner, mounted on four small turned wheels, travels; this runner is constructed with two wrought-iron side plates or cheeks, about $\frac{1}{2}$-inch to $\frac{5}{8}$-inch thick; at the top part, on each side, two rollers, 4 feet diameter, are provided, running on turned steel pins; at the lower part of the plates a hook is supplied, which is secured by a turned pin fastened by screwed nuts, which passes through each plate; near the top of the plates, under the gantry girders, two distance pieces or stays are provided and secured by bolts and nuts. The distance between the centres of the wheels must not be less than 14 inches. The runner is guided by

the inside of the posts rubbing against the lower flange of the girder. When the distance to the traveller does not exceed 15 or 16 feet, the runner may travel on the top flange of the gantry girder; in this case two roller wheels are provided the same width as the flange; in other respects the details of the runner are the same as before. At the hook, a pair of differential blocks may be attached for raising the load.

Screw Lifts.—For the purpose of raising and lowering loads at one spot, a fixed girder and carrier, to which is attached a screw, may be used. The screw has a capstan fitted to it, also a gun-metal nut. The diameter of the screw depends upon the load to be lifted; $1\frac{1}{2}$ inch diameter is sufficient for 2 tons, and 2 inches diameter for 4 to 5 tons load; the screws should have square threads, and be made of steel. The screw may be operated, if preferred, by a pair of bevel wheels, one being fitted with a screwed nut held in its place by a bridge casting; the horizontal spindle, or rod, to work the wheels may be led any desired distance, and be operated by an endless chain working on a spocket wheel keyed on this spindle. These are very useful lifts; the cost is small, added to which they are perfectly safe.

Differential Blocks.

These very useful apparatus have been most extensively used, and in various modified forms. The great advantage gained by their use is: when raising, the load will stand without making the chain fast; and in lowering, it can be done as required, and with no danger of the load running away. The chains want renewal in about two or three years when much used, as the links slightly stretch and get out of pitch; this causes the chain to slip upon the wheels. These machines have stood the test of many years, and from the Author's experience of their use, extending over about thirty years, they can be confidently recommended.

Useful application of the above.—A rail can be fixed to the roof or to the main timbers under the ceiling of a building, and a small carriage on two wheels, with a hook at the bottom, can be run on the rails; and by means of one of the above blocks a load may be lifted

and run to any part of the place. The rail may be curved if not of too sharp a radius.

To deliver sacks of corn, etc., from a doorway to a distant part of the warehouse, one rail is fixed with an incline *from* the door to this spot; it ends in a curve, and another rail is fixed inclined the other way back to the same spot. A small carriage mounted on wheels runs on the rails, the carriage being suspended under the rails. These are very useful machines, and can be easily constructed by any handy smith. The patent blocks must, of course, be obtained of the maker.

Jacks.

There are several forms of this simple and useful apparatus, viz., Haley's Rack, or Screw Jack; these are made in two forms, "tripod" and "bottle;" "Hydraulic Jacks," "Traverser Jacks," both screw and hydraulic; each of these will be separately described.

Haley's Jacks.—These are made to operate by means of a wrought-iron or steel pinion working into a cut rack, also of wrought-iron; on the spindle of the pinion at one end, a double headed winch-handle is keyed; a ratchet and wheel is also provided to hold the load. At the top of the rack a double claw is forged on, as well as one at the foot; by means of these the load is raised. The older type of jack frames are made of hard wood, plated with iron at the sides and bottom; two spikes are provided at the base to give a hold in the ground or timber on which they are placed; these are very simple and useful machines; although they have been improved in some respects, the old type still answers its purpose.

Improved Haley's.—This is a modification of the old plan; in this case a screw provided with an enlarged head is used instead of a rack to lift with. A worm wheel, carrying a gun-metal nut, is placed in a recess in the block of the rack; the bosses at top and bottom bear upon gun-metal plates; a worm keyed on a cross spindle works into the worm wheel, and on the end of this spindle the winch-handle is keyed. The body of the rack is either made of wood and plated with iron as before, or the whole may be made in iron; it may be stated, the wood blocks are usually preferred, as they are more easily moved about.

Screw Jacks (Bottle).—These consist of a conical hollow casting, having short spikes cast at the base; the top part is bored out, and the boss faced on the top. A screw-nut with a square thread is fitted into the boss. A screw of wrought-iron, about 12 to 16 inches long, works in this nut, the top part of the screw is made with a square enlarged head; on this the load is lifted; under the head, at a part also enlarged, four holes are drilled; short bars turned on the ends fit into these holes, and by their means the load is raised. These apparatus are made in various sizes; as to the diameter and height of the cones and the diameter of the screw, the latter does not usually exceed 2 inches diameter, with a range of more than 12 inches to 15 inches.

Screw Jacks (Tripod).—These are made in the same manner as the above as to the screws and nuts, but instead of the conical casting or bottle, a tripod of wrought-iron is employed; this is constructed with a boss which is bored out, and in which the gun-metal nut is fitted; the boss has three rods or stands forged on it; these are about 1½ inch to 2 inches diameter; they rest at the bottom on a ring of iron about ¾ inch to 1 inch thick. When very heavy loads have to be lifted, with a long range, this kind of jack is very useful, the screws are made from about 1½ inch to 4 inches diameter, and from 12 to 24 inches range; the height of the tripod and its strength depends upon the amount of range of the screw.

Hydraulic Jacks.—These are patented machines; they consist of a ram and cylinder, with a small pump at the base worked by a lever. At the top a large head is formed, by means of which the loads are raised. All the parts of the apparatus, except the pump, are made of cast-iron, the ram works through a leather collar placed near the top of the cylinder. These jacks should be used carefully, as they will not suffer rough usage, and for this reason the smaller sizes are not so often employed—for outdoor work especially—preference being given to Haley's, or screw jacks. Hydraulic jacks are made to raise from 1 to 30 tons.

Traverser Jacks (Screw).—These are made in the same manner as the tripod or bottle-jacks, except that they are, in addition, provided with a cast-iron base, on which the conical casting or tripod rests, and which slides in grooves in the base plate; being operated by a lower screw and nut, with hand-gear to work it,

distinct from the gear for the lifting screw. These jacks are usually only made for heavy weights; two or more are employed to raise the load, and by means of the traversing movement they can be shifted a distance equal to the range of the screws. They are most useful for the erection of work both indoors and as well as outdoors. The lifting range is not made of any great height, but the machines are made of sufficient power to shift loads of from 2 to 30 or 40 tons. It need hardly be stated, all the work must be of the highest class, and that all the parts must be made of great strength, proportionate to the load to be moved.

Traverser Jacks (*Hydraulic*).—These are constructed in the same manner as the hydraulic lifting jack described. They are provided with a base-plate in the same way as the last. The traverse movement is given by a small horizontal ram and cylinder, operated by a pressure pump in the same manner as before. These apparatus are employed for moving very heavy loads, and are made in powers from 10 to 100 tons. In places where hydraulic pressure-pipes are at hand, worked by an accumulator, the water-pressure can be taken from the mains; this is specially applicable where a large number of these jacks are employed; the lift in this case is more equally taken, and on this account the strains are also equal, and simultaneously put on. In moving a boat or vessel in a graving or other dock, or when upon the slips in a building yard, this equal distribution of the pressures is a matter of great importance. There are many purposes to which these useful machines can be applied; special modifications in their arrangements are made for particular cases. In the erection of heavy iron and bridge work, they are of the greatest service, and can be employed in a variety of ways that would soon suggest themselves to a skilled man when placed in a difficult position.

CHAPTER III.

HAND-POWER LIFTING MACHINERY.

THE most important machinery of this kind are lifts for warehouses and public institutions. As this class of work has not in many cases received that attention its importance deserves, full details are hereafter given, which will enable the architect, surveyor, or engineer to specify what he requires. Most of the examples described are from works actually executed by the Author, and which have stood the test of many years' successful and safe working. Many modifications may be made from the various types given to suit special cases without altering the general principles on which they are constructed. A large margin of safety should always be allowed to meet unusual strains, to which lifting machinery of all kinds is usually exposed. The author advises designers and users to deal only with manufacturing engineers who have made this work a study, and not to allow anyone to tender whose work does not bear the highest character. Good work of this kind cannot be obtained *cheaply ;* where offers from different makers vary widely, it is reasonable to suppose the class of work will not be the same.

WAREHOUSE LIFTS FOR 10 HUNDREDWEIGHT (Drawings Nos. 77, 78, and 79).

The Cage, or Ascending Room, should be constructed as follows:— The lower frame should be formed of a ring of L iron, 3 inches by 3 inches by ½ inch; this ring should be welded into a solid frame; on this is bolted oak or beech boards, ploughed and tongued, 1¼ incn thick, to form the bottom, with battens running transversely, firmly

screwed on the under side to strengthen the floor. The front, or loading edge of the floor, should be protected by an iron plate, let in flush with the top of the boards. Two suspending irons at each side are riveted to the lower L-iron frame, with two cross lifting bars riveted at the top, say, 6 feet to 6 feet 6 inches high from the floor of the cage (the height of this will depend upon the size of goods to be lifted); these bars should be 4 to $4\frac{1}{2}$ inches by $\frac{1}{2}$ inch each; the ends should project $2\frac{3}{4}$ inches beyond the suspenders, to form rubbing guide plates, the corners of which must be rounded. On the bottom of the two suspending irons two 4 inch by $\frac{1}{2}$ inch plates are riveted on each side, for the lower guides. To keep the suspenders rigid, two diagonal rods $1\frac{1}{4}$ inch diameter must be riveted on each side to take the thrust. At the centre of the two cross bars a wrought-iron plate is riveted, with a hole to receive the shackle of the lifting chain or rope; the hole should be drilled and the edges rounded to prevent any cutting of the shackle.

The Guide Bars are T iron 3 inches by 3 inches by $\frac{1}{2}$ inch. The ends of each length should be squared, and the joints covered by back plates $\frac{1}{2}$ inch thick, well riveted on. The bars must be erected vertically and dead plumb on the faces, and be bolted to the joists at each floor; if the height between the floors exceeds 9 feet, they must be fixed to intermediate timbers to keep them rigid; after they are fixed in their place, the front edges must be filed down and all irregularities removed, care being taken to make the joints fair. The clearance at any part between the rubbing guides of the cage and the guide bars must not exceed $\frac{1}{8}$ inch.

The rope working the lift passes over a spocket wheel at the top of the well hole, of a diameter equal to half the width of the cage, and the centre of the counter-balance at the back wall. In most cases the wheel will be about 20 to 24 inches in diameter at the pitch line; the shape of this groove is very important. The rope is gripped by the groove of the wheel, and passes direct to the top of the counter-balance.

The Counter-balance.—This is a flat iron weight, with grooves planed out at each side. The top part of the weight is provided with a pocket, for the purpose of adding loose weights as required. A wrought-iron shackle is fitted at the centre, and to this the other end of the lifting rope is attached. The weight of the balance is

about 20 lbs. less than the cage; this is generally sufficient to allow the cage to lower by gravity when the gear is thrown out.

Two L-iron guide bars, $1\frac{1}{2}$ inch by $1\frac{1}{2}$ inch by $\frac{5}{16}$ inch, are fixed on timbers and placed at the back of the table. The same remarks as to fixing the main guide irons apply to these. The counter-balance weight should not be more than $\frac{1}{8}$ inch clearance at the bottom of the grooves. The thickness of the counter-balance should be about 4 inches; it should be made narrow and long, to form a better guide.

Gear to work Lift.—A large spocket wheel, over which an endless rope operating the lift passes, is keyed on to a shaft, on which is also keyed a spur and brake wheel. Motion is given to the lift by an endless rope passing through all the floors; thimbles are fixed at each floor to prevent the rope cutting; this rope works a large spocket wheel, say, 3 feet 6 inches to 4 feet in diameter, keyed on to the first shaft at top, on which is a pinion with a sliding clutch; this pinion gears into the spur wheel on the spocket lifting wheel (second) shaft. By means of a lever and rods passing through all the floors, the gear can be thrown in and out, so as to allow the cage, empty or full, to fall by its own gravity. A brake wheel is also keyed upon the spocket wheel shaft; a cord from the lever passes through all the floors; the lever is fitted with a counter-balance to throw it out of gear. The rod working the clutch gear is made to swivel at the top, and is provided with a handle at each floor; when the rod is raised or lowered to throw the spur wheels in or out of gear, the handle is turned half-way round, and rests upon stops, which are fixed to the side posts at each of the floors.

The endless working rope at the bottom of the lift passes over a grooved wheel of the same diameter as that at the top; it runs on a turned pin on a bracket, in which is a long slot; this allows for expansion and contraction of the rope, according to the state of the weather. In a long rope for, say, a lift of 50 feet, this will alter from 3 to 4 inches in length, especially in damp weather. In cases where the foundations may not be dry, the wheel must work in a cast-iron box sunk in the ground, to protect the rope from wet and moisture.

Brakes.—There are two plans of working these: first, by keeping the brake *always on*, by means of a counter-balance weight on the

lever; second, *brake off*, and a rope to pull the same into gear. The first-named is the safest plan. In case the man working gets nervous or frightened, he usually lets go the rope; the brake being then in immediate contact with the brake wheel, holds the load, and so saves an accident. In the latter case, where the brake is held in gear by the rope, small lengths should be spliced in it at each floor, with iron cleats to make fast to, when the cage is required to be held at any point. The brake straps should be lined with beech, well fitted to the brake wheel. Ample power should be provided in the levers to ensure one man holding the maximum load safely.

Safety Gear, to prevent accident in case the rope breaks, should be fixed at the top of the cage. This gear is specially described (see p. 140).

Safety arrangements.—Chains should be fixed on side posts at each of the floors; the lift hole should be lined at the sides, to prevent goods falling out from any of the floors. In warehouses and like places it is advisable to provide sliding shutters; these can be made of wood when the enclosure is constructed in timber, but should be made of iron plate when the enclosure is in brickwork.

Hand Power Passenger Lift.

The Drawing No. 79 shows a lift for raising passengers suitable for an infirmary. The general system on which it is worked and the gear for operating it is much the same as in the warehouse lift shown in Drawings Nos. 77 to 79, and described at p. 177. The details of construction differ in the following particulars:—

The cage or ascending room is made at the lower part with a welded angle-iron frame 3½ inches by 3½ inches by ⅝ inch, the roof is also formed of a welded frame of the same description. At each corner of the lower frame L iron 3 inches by 3 inches by ½ inch suspenders are riveted to gusset plates, and are connected in the same manner with the upper L-iron frame; the frames are braced on three sides as shown; the bars are riveted to the corner gusset plates of the upper and lower frames. At the top of the cage two transverse bars of L iron 4½ inches by 4½ inches are riveted, and at the centre have a plate 12 inches long, by means of which the cage

is suspended from the lifting rope. At the top and at the bottom of the cage on either side rubbing guides of cast iron, lined with gun-metal, are bolted. The floor of the cage is formed of oak boards, grooved and tongued, 1¼ inch thick, provided with oak battens on the under side; the boards rest on and are bolted to timber beams laid on the L-iron frame; countersunk bolts pass through from the top of floor to the under side of the frame. The sides are lined with ¾-inch match-boards, grooved and tongued, which are held in their position by a skirting-board at the base and cornice moulding at the top. The roof is lined with 1¼-inch boards, grooved and tongued.

The cage is provided with a safety gear similar to that shown in Drawing No. 69; this is not shown in its place, Drawing No. 79.

The Guide Bars are two in number, one placed on either side of the loophole; they are of cast iron, with V faces, which are planed; they are fixed in the same manner as described for hydraulic lifts, p. 61; they are bolted to side timbers.

The Counter-Balance Weight works in a groove in the brickwork outside the wall of the loophole; it is constructed and is guided in the same manner as that described at p. 62.

The Lifting Rope is 4½ inches circumference; it is attached to the centre plate of the cage by a special shackle; it passes direct from the cage over the spocket wheel placed at the top of the well-hole to the centre of the counter-balance weight.

The Endless Rope is 3½ inches circumference, and works over spocket wheels placed at the top and bottom of the lift hole; these wheels are 6 feet in diameter at the pitch line, giving ample room at the front or entrance to the cage to pass through.

Working Gear for the Lift.—This is placed on top, and is of the same general design as for the warehouse lifts, Drawings Nos. 77 and 78. It is arranged in a different manner to permit the endless rope wheel in this case to be placed in the front of the lift.

Enclosure.—The lift in this instance is enclosed in brickwork; the entrances at each floor are by means of iron doors, which are kept closed, and are arranged to open only from the inside by the attendant who travels with those ascending or descending by the cage. It will be noticed that every precaution has been taken to ensure that the motion is easy and perfectly steady.

Sundry Details of Lifts.

Well Holes for Lifts.—In erecting new buildings it is advisable to construct the well holes in brickwork, to save the risk from fire. In several instances, in the Author's experience, when a fire has commenced in the basement or ground floor of warehouses they have been destroyed by the flames rushing up the lift hole and firing each floor in its ascent. Experience has shown that where lift holes are of brickwork, and even only provided with doors or shutters of wood at the various floors, the flames have simply run up to the roof and burnt that portion, leaving the rest of the enclosure almost untouched. The Fire Insurance Companies often reduce their rates when lifts are enclosed in the manner described. The Author advises warehouse keepers and others, in case of fire occurring in the lower part of the place in the daytime, if possible, to have all the lift hole doors closed at once; the damage will then be confined to the interior of the same. Of course, every night all the shutters and doors should be closed and locked.

Doors to the Lift Hole at the various floors.—For these the Author prefers iron, but if made of wood they are usually made like an ordinary room door or in the form of a sliding shutter. In places where the public have admission, the doors and shutters should have patent locks, and in the case of passenger lifts they should only be capable of opening by the attendant in the cage from the *inside* of the lift hole. In the case of food or goods lifts the shutter should be fastened by spring locks at the landing sills.

Ropes are the most preferable for lifting, and should always be of ample power; for 10 cwt., not less than 3½ inches circumference; 15 cwt., 4 to 4½ inches. The endless ropes should be 3½ inches in circumference; this gives a good grip to the hand of those who work the lift. They should be of the best white hemp.

Brake Ropes should be 2½ inches to 3 inches in circumference, for the same reason, and of the same quality.

It is advisable to examine the ropes and all the gear once per month; and also to test the safety apparatus, to make sure that all

is in perfect working order. All parts of the gear should be oiled once per week, and the guides greased once in every three or four weeks.

The various parts of the lift should be made of sufficient strength to stand the shocks to which it may be liable from having the brake suddenly applied when a heavy load is in the cage, or from the rough usage that such apparatus get from the class of men who usually have to work them.

Warehouse Lift, with Gear below (Drawing No. 80).

There are many cases where goods have to be raised and lowered from the ground floor to the basement, and where the gear cannot be fixed at the top; in this case all the working gear is placed in the basement, and in some cases partly underground.

The Table, or Cage, is constructed in much the same way as before described, except that the framing for guides, lifting bar, &c., is inverted. The least depth below the table for the iron cross bars, to which the rubbing guides are attached, should be 3 feet; this is for the purpose of keeping the guide plates at a sufficient distance apart, to ensure easy working, and also to prevent vibration.

The table and framing are sunk in a recess in the floor of the basement, formed by a rebated curb of oak. When the table is run up to the top, it forms part of the floor, and can be secured by bolts for safety, or may have a lock, as described for the bank lift at p. 65, but of a less expensive kind. The lift shown has a table of wrought-iron which closely fits into a cast-iron frame in the floor at the top, and so makes all fire-proof.

The Guide Irons are either of cast iron and planed on the faces, or they may be T iron, as before described; those for the counter-balances will be much the same as before, except that the latter, with its guides, may require a different arrangement to suit each particular case.

Working Gear is usually a special crab motion fixed to the floor of the basement; this is fitted with a winch handle and fly-wheel, or with grooved wheels and an endless rope. Two chains are attached to the cross bars *under* the table, one on each side, passing over two

grooved chain wheels, to the barrels on either side, which are placed under the floor line in the basement; at the back on either side two other chains pass over pulleys, and are attached to the counter-balances, which slide in L-iron guide bars, as before described.

Warehouse Lift, with Gear below. A.

This is a modification of the above plan; to suit special requirements of the work and building, it is constructed as follows:—

Table and Guides, &c., are arranged as before.

Working Gear consists of two endless pitch chains, one working on each side of the table, which are attached to the cross bar under the table and pass over two pitch chain wheels at the top placed under the ground floor, and two at the basement sunk beneath the flooring; motion is given from a crab gear, as before described, and by means of another endless pitch chain working on wheels on the shaft on which the two lower pitch chain wheels are keyed. Brake gear, &c., is also attached to this shaft in the same way as before described.

No wheels (except the crab) are above the floor line, either at the top, or ground-floor, or in the basement.

Warehouse Lift, with Gear below. B.

This is constructed on much the same plan as above, except that the shaft, having the tooth wheels gearing on to the pitch chain, is fixed at the *top*, under the table. Two pitch chains, one on each side of the table, are attached to the lifting cross bars, and pass over the tooth wheels to a counter-balance on each side. On the shaft at the top is keyed another tooth wheel, which, by means of an endless pitch chain, is geared to a crab motion of the same construction as before.

This class of lift is specially suited to a cellar where there is little head room, and where, owing to the foundations and other causes, no gear can be worked below the basement line.

The chains for this class of lift must be of the best kind; a good form of which and one much used by the Author, consists of links,

square in shape, made of round iron, connected by flat S links made of hoop iron, secured by one rivet at the lap. They are most reliable chains, not subject to fracture, and are easily repaired by putting in new links; great care is required in the manufacture to ensure that all the links are exact to pitch.

There are several other adaptations of the above class of lift; but as they are only used for very special circumstances, they need not here be noticed.

Cellar Lifts, Inclined (Drawing No. 81).

Lifts of this type are principally used to raise casks of wine, beer or oil. The gear for raising and lowering the load is by a crab motion placed near the wall, from the barrel of which a chain passes over a grooved wheel to the centre of the table, to which it is attached by a plate and shackle.

The table is made with an angle-iron frame, to which a wood floor is secured by bolts and nuts; the top frame is riveted to an iron framing below, which is fitted with four friction wheels provided with flanges.

The Guide Girders are of wrought iron, trough-shaped, and on the lower flanges of these the wheels of the table run; at the top part of the girders, near the ground floor, a cross girder takes the chain wheel and its carriage.

The details of the counter-balance and the guides are much the same as in the previous lifts, and must be arranged to suit the special circumstances of the case. A pit is sunk under the floor of the basement, into which the table sinks when at the lower level. Stairs are formed between the trough irons, so as to afford an entrance to the cellar.

Screw Lifts for raising 14 cwt. (Drawing No. 82).

The table is made the same as described for No. 80. On the under side is fixed a screw 3½ inches in diameter, cut with a square thread, having a flange on the top; it works in a gun-metal nut, fitted in the boss of a bevel wheel, which is placed under the

floor line of the basement. The screw rises and falls in a pipe which is sunk in the ground, and is operated by bevel-wheel gear and fly-wheel. The table is provided with two counter-balance weights placed at the back wall, running between L-iron guide bars, in the same manner as before described.

To prevent undue friction and to relieve the pressure on the gun-metal nut, the weight of the table and screw are overbalanced; the wheel in which the nut is fixed has a groove cut in the boss, and a clip working in this groove attached to the cylinder head prevents the wheel from lifting.

This kind of lift is rather slow in working; the speed, with one man and 14 cwt. raising 10 feet, being about two minutes to two minutes and a half. It is, however, absolutely safe, and is well suited for raising and lowering valuable goods, such as casks of wine and spirits; it also possesses these advantages—it must be worked down, and at about the same speed as when raising; it cannot run away if left alone, and does not require making fast at any point of its *ascent* or *descent;* the motion is steady, and there is no noise in working. The wear and tear is very small. A lift of this type, designed by the Author for a large firm of wine-merchants, was in constant use for upwards of sixteen years before it required a new nut; after a careful examination of all the parts, no other material wear had taken place. It had been in constant use all the time named; the firm had been entirely free from accident during the period it had been in use.

Rack Lift.

This is constructed in the same manner as the above as to the table, guides and counter-balances, but is worked by means of a toothed rack attached to the under side of the table in lieu of a screw. This rack should be made wide, and of good pitch; preferably it should be made in wrought iron, and the teeth machine-cut. It should be well guided at the sides, in the same manner as described for the hydraulic lift, p. 64. The crab, or working gear, is much the same description as before. The pinion gearing into the rack should be of wrought iron, pitched and trimmed.

This form of lift is not generally to be recommended; it is not so safe as the others described; where, however, the goods are not of much value, and are not liable to fracture in case of falling—the action of the gear being rapid both in raising and lowering—they can be used with some advantage. These lifts are sometimes driven by steam power; in this case the driving gear should be toothed wheels geared with wood and iron teeth; belts are not safe to use owing to their liability to slip.

Endless Lifts.

These may have hand motion applied; they are described at p. 150, and are made in various forms. They are suitable for light packages of one size and weight, and where the goods to be transferred are in large quantities, and for the purpose of passing them from floor to floor, either for storing or to another part of the place where the next process in their manufacture is to be carried out. They work slowly, and have to be designed to suit the special requirements of the case; they are simple in construction, do the work well, and are not liable to break down; the wear is very small. They should be carefully designed and well made.

Rope and Bucket Lift.

This is a very useful lift for raising books, papers, and other light goods, either from one floor to another or up a staircase, and more especially where there are no means of fastening anything to the floors or other parts of the building. Either single or double wheels are fixed at the top and bottom. An endless wire or hemp rope passes over these, having buckets or pockets attached at various points of the rope; in these receptacles the books or other things are placed. They are noiseless in action, very simple in construction; their cost is small, and they can be fixed by any intelligent mechanic.

Lowering Machine with Gear below Table (Drawing No. 84).

Machines to *lower* casks and other goods are self-acting, and are constructed as shown in the drawing, and in the following manner:—

The table, guides, and counter-balances are made in the same manner as before; the weight of the table is overbalanced by the counter-weight; this is to allow the table to rise by the superior gravity of the balance weight directly the load is off.

No gear is required except the top wheels, shaft brake, and lever. As this class of machines is subject to very heavy shocks, they must be made with all their parts rigid so as to be free from any vibration. In the case of beer casks, the type shown in Drawing No. 83 is the most suitable for use when any gear can be placed overhead.

The brakes in these machines should *always be on*, and the counter-balance on the brake lever made heavy for safely holding the load. The action of the lifts is very rapid, and for lowering goods it is the quickest and most economical process that can be adopted.

Lowering Machine for 10-cwt., with Gear on the top floor.

This machine is constructed in the form shown in Drawing No. 83, with the controlling gear placed over the cage or table in the upper floor. In this case the table is provided on the upper side with vertical side and transverse irons, and fitted with rubbing guides at the top and bottom on each side; these are placed 6 feet 6 inches apart, and run between T irons 3½ inches by 3½ inches; as in the former type, these are prolonged in the upper floor, and are fixed to the top framing. A rope of hemp or leather 4 inches circumference is attached to the plate at the centre of the transverse bars, and is carried over a spocket wheel which is turned in the groove and grips the rope; it will be understood that it does not bottom on the bottom of the pulley in this case. The wheel is made a diameter at the pitch line equal to the distance between the centre of the cage and centre

of the counter-balance; in the case now being described it is 2 feet 3 inches diameter. The rope passes direct from the wheel to the balance weight. This is made in the same form, and is guided in the same manner as the former type described at p. 188. The top gear consists of a spindle or shaft 3 inches diameter, running in bearings carried by the top framing. A brake wheel 2 feet 6 inches diameter and strap, lined with hard wood, is also keyed on this shaft, brake lever and working rope with counter-balance gears is also provided. The weight is arranged on the lever to keep the brake always on; it is released as required when the goods are to be lowered. When it is to be used for lowering casks of beer, the table at the centre of the floor has a hole cut out, a spring is provided at the basement against which the cask strikes, and is in this way driven off the table. The cage is overbalanced in the same manner as described at p. 188. India-rubber springs are provided under the weight, as well as under the table, to take off the shock if the goods are let down too suddenly. This type of lift, as well as the other, was introduced by the Author some years since, and has been largely used. This is the most rapid system for lowering goods that can be adopted. It will be noted that all parts of the machine are very strong and well braced in all necessary parts; this is absolutely essential on account of the heavy shocks to which they are liable.

House Lifts for Food, etc. (Drawing No. 85).

These apparatus are made as shown for large establishments, the cage being of a size suitable to the work to be done; the loads raised are not more than ½ cwt. to 1 cwt. each time, the latter weight applying to public places only.

The Cage.—The lower frame is made of light angle iron, say 2 inches by 2 inches; the top frame is of angle iron; the corner suspending irons 1½-inch angle iron. The top and bottom frames are diagonally braced by flat iron on three sides; the floor is of oak, and the inside is lined with pine, provided with one or more shelves according to the requirements of the case.

The guide bars are 2-inch T iron, which are fixed to the timber

enclosure. The counter-balance guide bars are $1\frac{1}{4}$ inch L iron, which are attached to the back wall in the manner shown.

The working gear consists of an endless rope working over a large spocket wheel, say, 30 to 36 inches in diameter, fixed to a shaft 3 inches diameter carrying a pinion which gears into a spur wheel keyed on the lifting wheel shaft. On this is also keyed a brake wheel, fitted with lever and counter-weight.

The manner of working and many of the details do not materially differ from the warehouse lifts for small loads.

The loop-holes or openings of the lift should be enclosed with sliding shutters at each floor, and be provided with a ledge to land the food, &c., on; this should be placed 3 feet above the floor line.

House Lifts, Double, and for Light Loads.

Where the weight does not exceed 25 or 30 lbs., two boxes made of wood are used; the rope is attached to the top of each box, and passes over a central grip spocket wheel; another rope is attached to the bottom of each of the boxes, and passes over a lower grooved wheel. The guides in this case are usually wood, and form part of the enclosure of the lift hole. The Author, however, prefers to use $1\frac{1}{4}$- to $1\frac{1}{2}$-inch angle irons for guide bars, as there is much less friction and no noise in working; the extra cost is very small.

Where the loads exceed that named, a spocket wheel is keyed on to the top shaft, and it is worked by an endless rope passing through the floors. In this case brake gear is provided, the working rope of which passes through the floors in the manner previously described.

Light Lifts.—The best system for lifts of this kind for hotel use is to provide one for each floor to ensure that the various things ordered get delivered to the proper place, and so confusion is avoided; this applies where special orders are given for various articles, and prevents any one on a lower floor taking them off, which often results in much confusion and loss of time. Above the lowest opening into the lift there is only one other situated at the floor where it is required to deliver the things.

APPENDIX.

HYDRAULIC WORKSHOP MACHINERY.

Hydraulic Drilling.

At page 105, *ante*, reference was made to the application of hydraulic pressure to driving *rotary* machines. The first successful application of this to drilling was made by M. Marc Benier-Fontaine in connection with the celebrated installation of hydraulic machine tools on Mr. Tweddell's system, supplied to Toulon Dockyard under the advice of Mr. Henry Chapman, C.E., in 1874. It was this engineer, also, who had the courage to introduce into this yard, on a really large scale, the punching and shearing machines described on page 98, *ante*. The drawings of the hydraulic drills are almost self-explanatory.

No. 86 shows a Brotherhood three-cylinder engine attached to a suitable framing; this can, of course, be modified to suit any special condition. The power of the engines, which are made in two sizes—one to indicate 1 HP. actual, the other ½ HP. —is transmitted through gearing to the drill spindle. In order to adjust this drilling-engine to its work, any ordinary adjusting form of standard is used, the hydraulic engine taking the place of the ordinary ratchet-brace; of course the increase in the rate of drilling and the number of holes done, as compared with hand work, is very great.

Extreme lightness is secured, first, by the small size of the cylinders of the engines themselves, which, when working at 1500 lbs., or even 750 lbs. per square inch, require them to be of very small diameter, and they are also made throughout of steel and gun-metal.

Drawing No. 87 shows another application similar to A, in which it is not possible to attach the engines so directly to the work. In this case the three-cylinder engine is placed on the floor of shop or deck of a vessel, and transmits its power by means of a "Stowe" flexible shaft to the drill. In one boiler-shop where this arrangement is used the cost of drilling holes in boiler-ends was reduced from 1*s*. 4*d*. to 4*d*. per dozen, and the work done very much faster also.

Drawing No. 88 illustrates yet another arrangement in which the three-cylinder drilling engine is attached to a frame, for the purpose of cutting out large man- or deck-holes. The plan shows the two arms carrying the cutters; the size of the holes cut can be varied from 15 inches to 30 inches diameter, or, if desired, oval holes can be cut out. The whole arrangement can be carried by two men; and a small hole at A having been first drilled, the bottom bracket B is connected to the top one C by means of the bolt D.

The great advantage of this machine is that it enables man-holes, &c., to be cut out after the vessel is plated and in the exact position required.

A modification of the preceding designs was very successfully used during the construction of H.M.S. *Victoria* at Elswick.

The time occupied in drilling in position the holes in the shell for the armour-plate bolts, was reduced from three hours by hand to twelve and a half minutes by the machine after it was fixed; and in some other work of a similar kind, the time occupied was reduced from nine hours by hand to one hour by the machine. These drills were worked from an accumulator from $\frac{1}{3}$ to $\frac{1}{2}$ a mile distant, the pressure being conveyed by means of flexible piping attached to the nearest mains.

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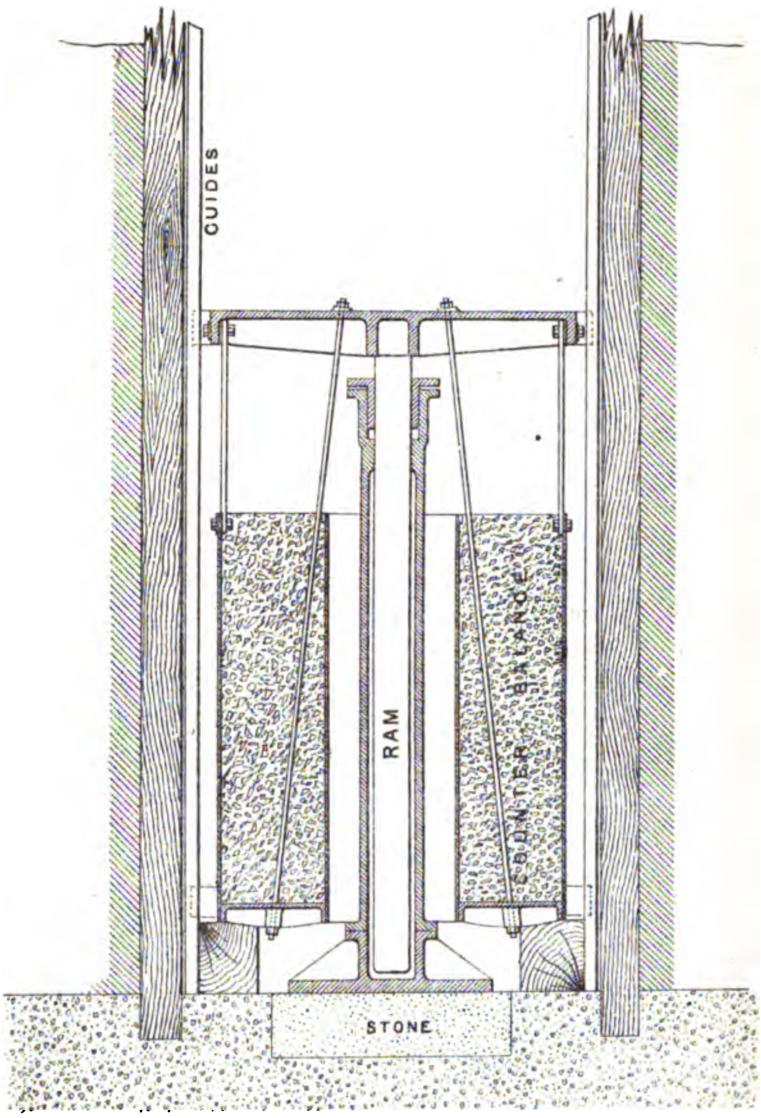
J.

L.

M.

LONDON:
PRINTED BY WILLIAM CLOWES AND SONS, LIMITED,
STAMFORD STREET AND CHARING CROSS.

ACCUMULATOR.



F. COLYER, M.I.C.E.

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HYDRAULIC LIFTING AND PRESSING MACI

TRIPLE EXPANSION COMPOUND CO

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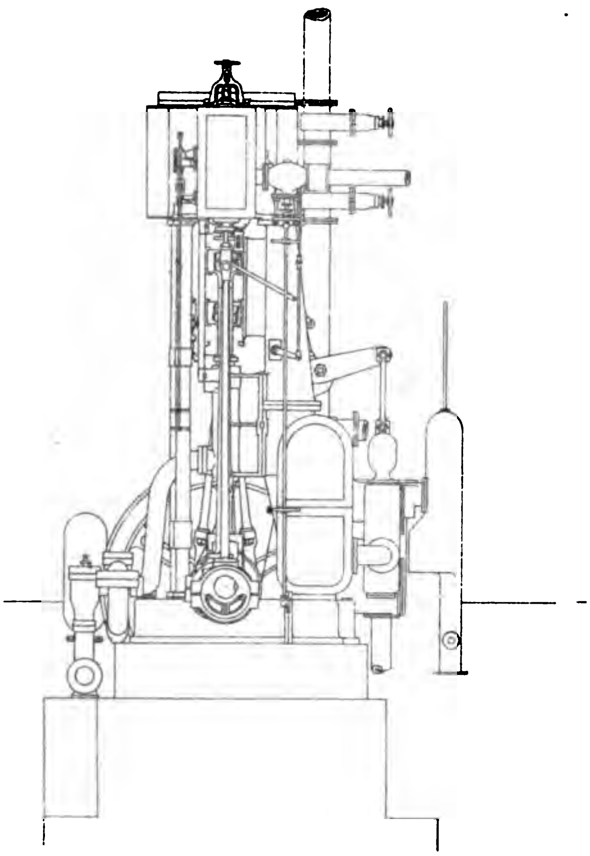
No. 5.

AS MADE FOR THE LONDON HYDRAULIC



CYLINDERS 15, 22, & 36 INCHES DIAMETER.
PUMPS = 5" DIAMETER. — SINGLE ACTING
STROKE = 2'-0"
STEAM PRESSURE = 150 LBS. PER SQ. IN.
HYDRAULIC PRESSURE - 800 LBS PER SQ. IN.

THE ENGINES TO DELIVER 250 GALLONS PER MINUTE AT A PISTON SPEED OF 210 FEET PER MINUTE.

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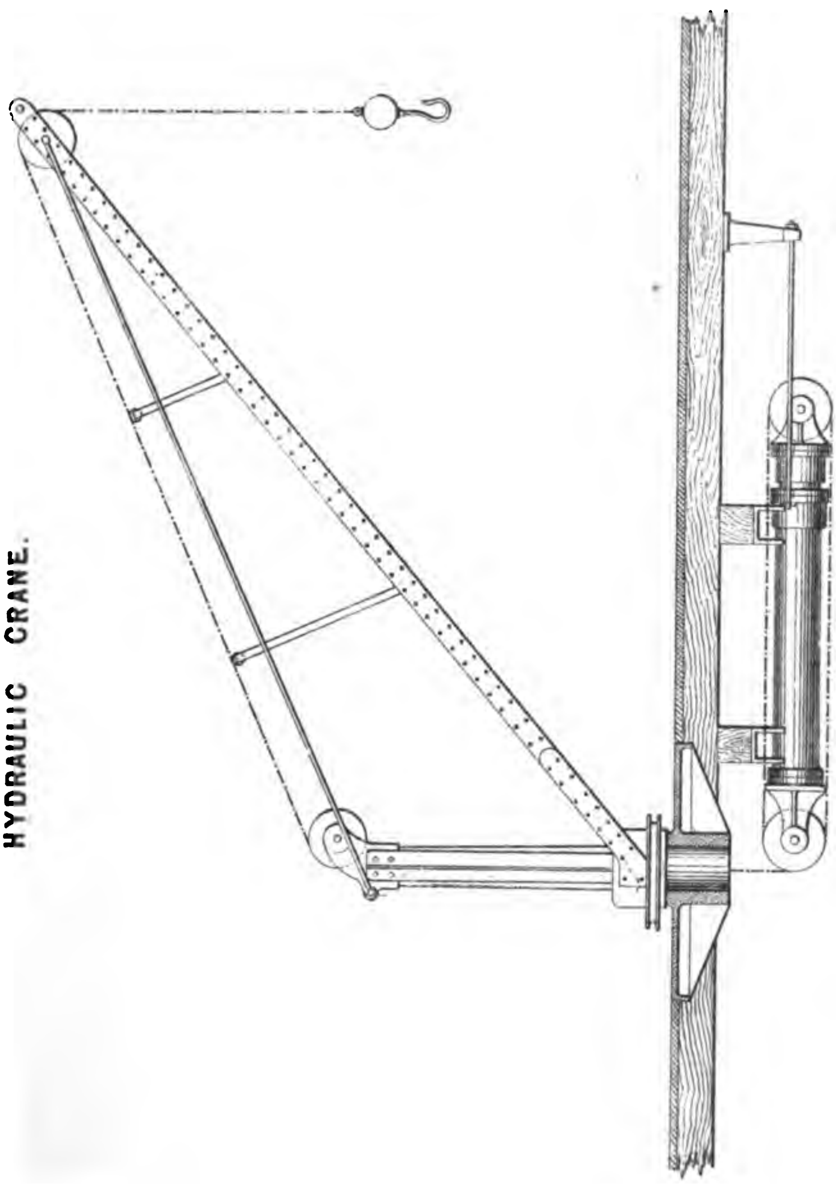
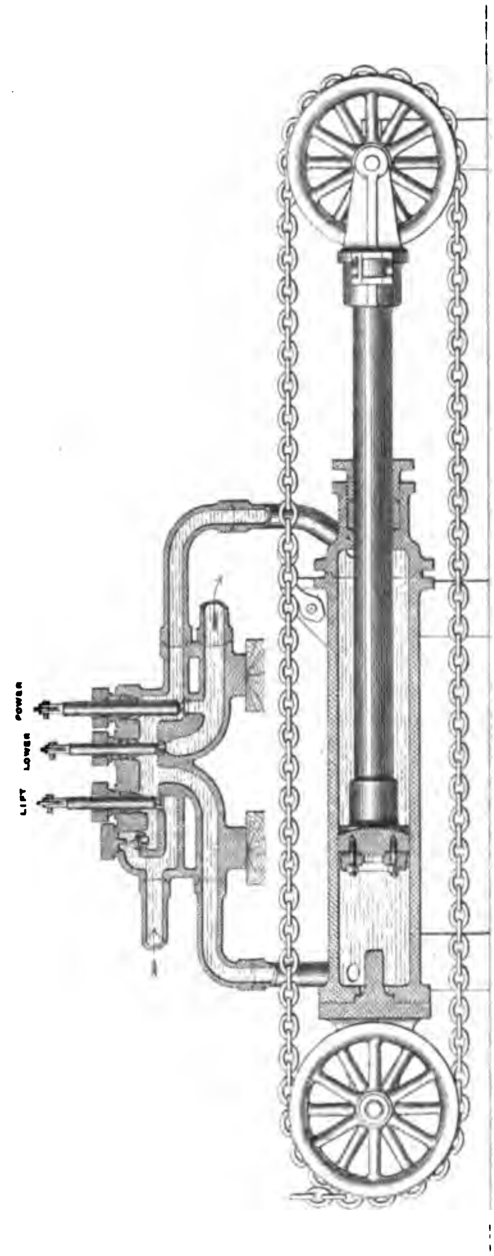


HYDRAULIC CRANE.

F. COLYER, M.I.C.E.

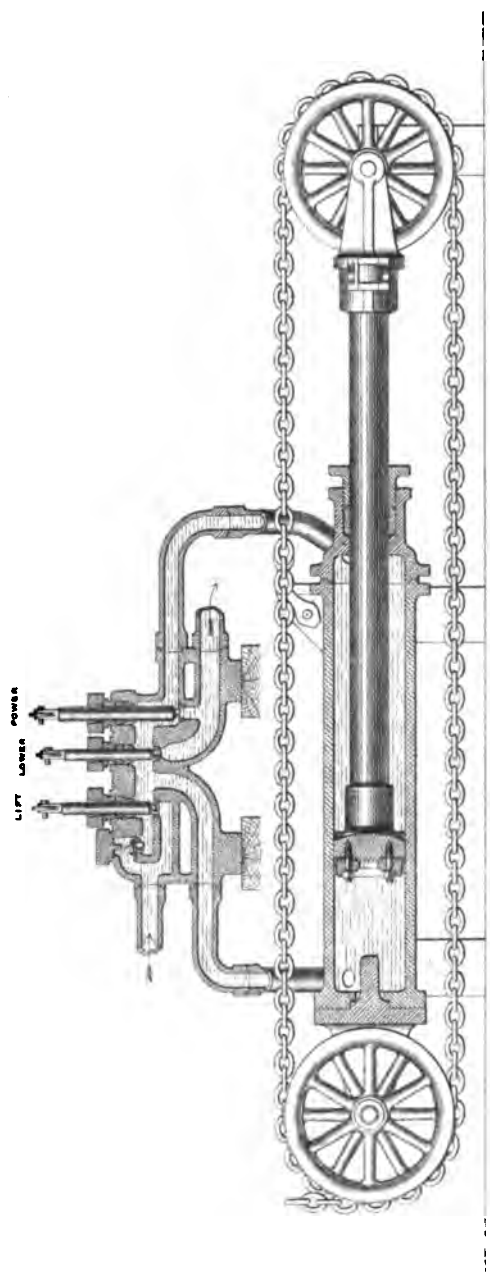
HYDRAULIC WORKING CYLINDERS



COMBINED PISTON AND RAM.

F. COLYER, M.I.C.E.

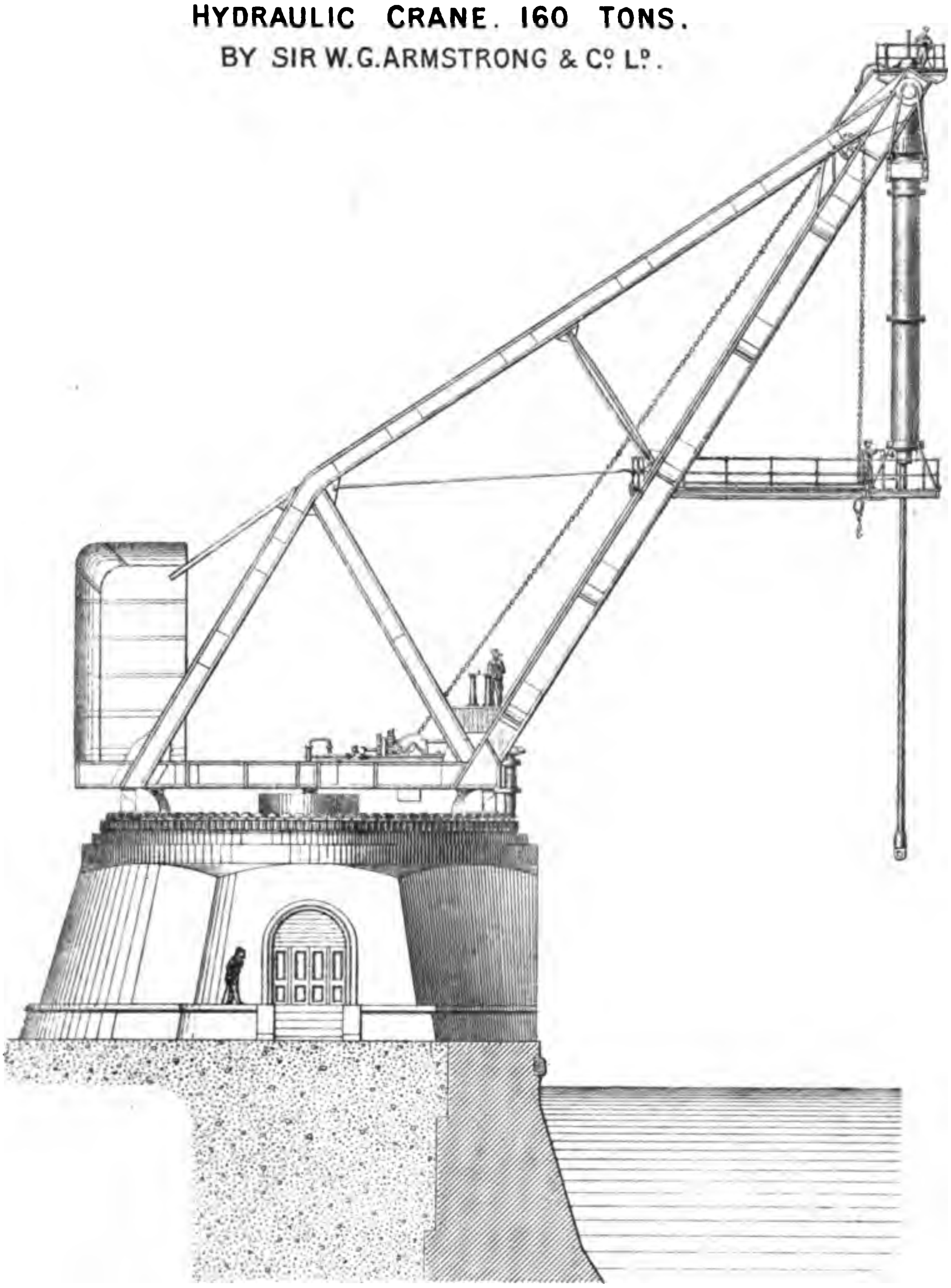
HYDRAULIC WORKING CYLINDERS



COMBINED PISTON AND RAM.

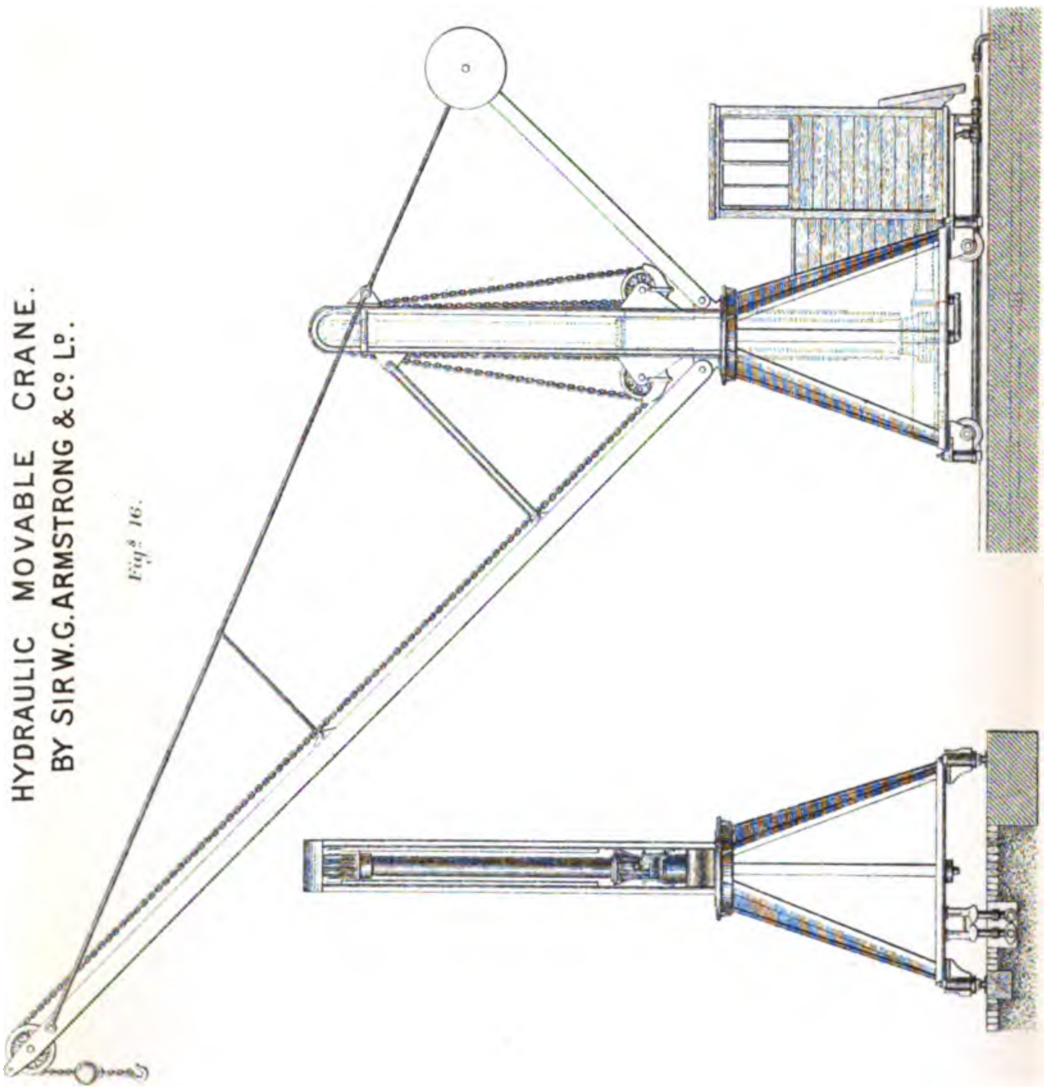
F. COLYER, M.I.C.E.

HYDRAULIC CRANE. 160 TONS.
BY SIR W. G. ARMSTRONG & Co. Ld.



SPEZIA CRANE.

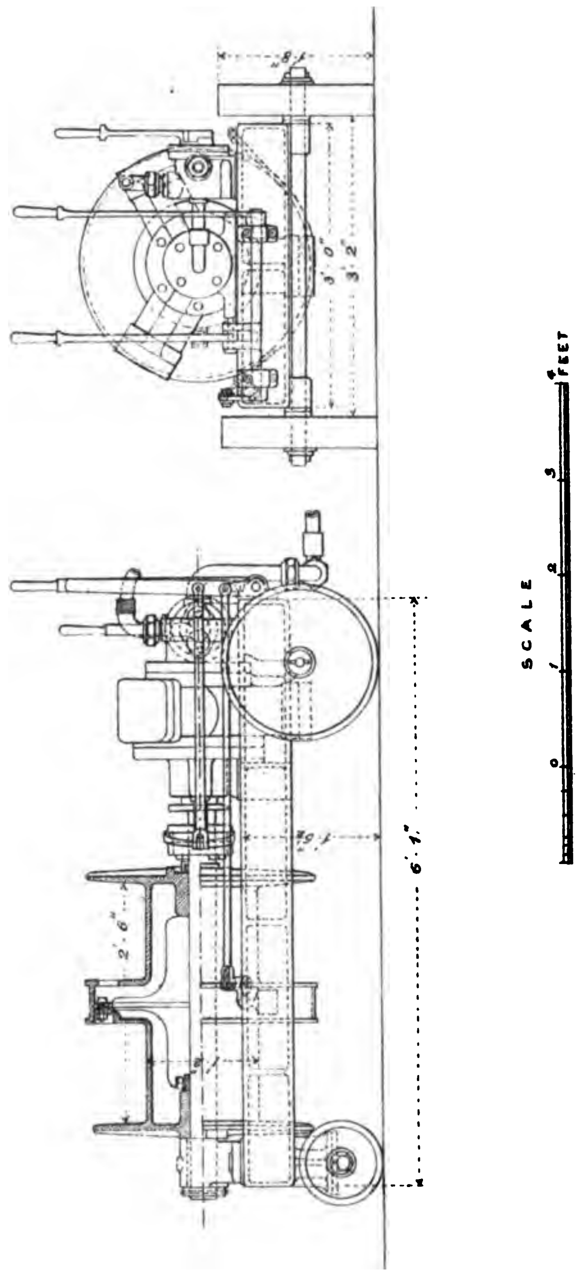
F. COLYER, M.I.C.E.



MOVEABLE CRANE.

F. COLYER, M.I.C.E.

ELINGTON'S PATENT MOVEABLE HYDRAULIC WINCH
WITH
BROTHERHOOD'S PATENT 3 CYLINDER HYDRAULIC ENGINE.



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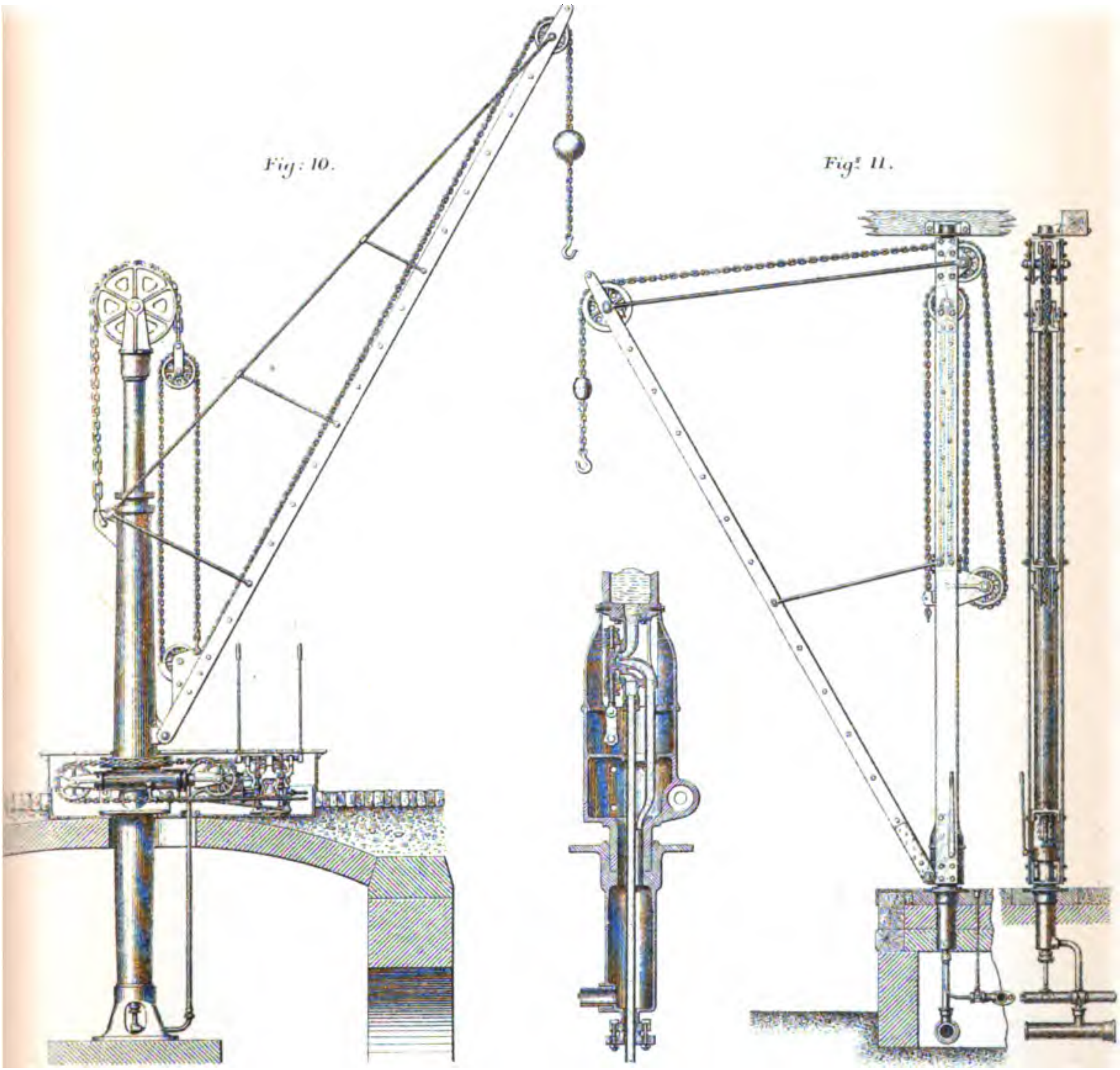
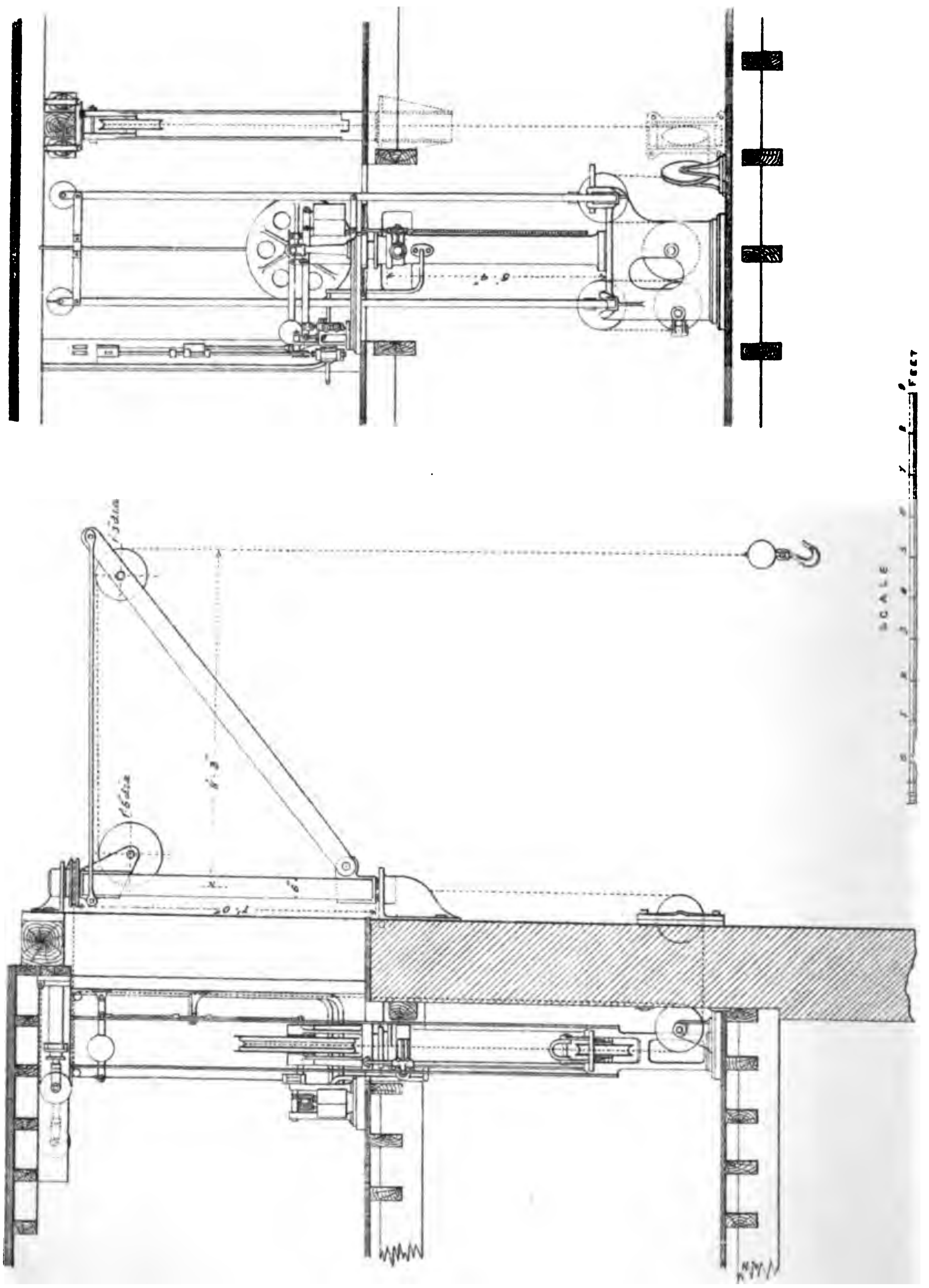
HYDRAULIC POST CRANE.
BY SIR W.G.ARMSTRONG & Co. Ld.



RAILWAY GOODS STATION CRANES.

DOUBLE POWER HYDRAULIC WAREHOUSE CRANE.

JOHNSON & ELLINGTONS PATENT.



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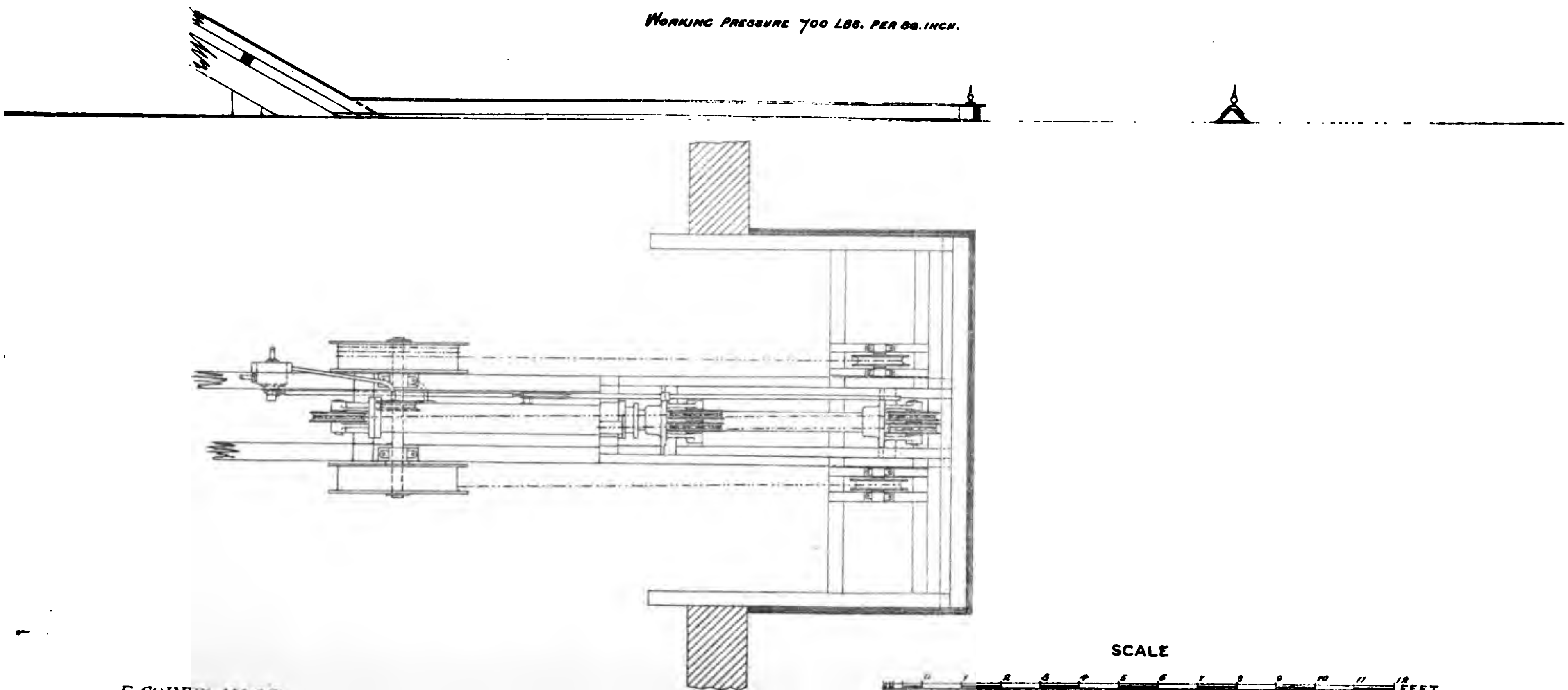
7 CWT. DOUBLE CHAIN SACK HOIST.

BY THE HYDRAULIC ENGINEERING COMPANY. CHESTER

WORKING PRESSURE 700 LBS. PER SQ. INCH.



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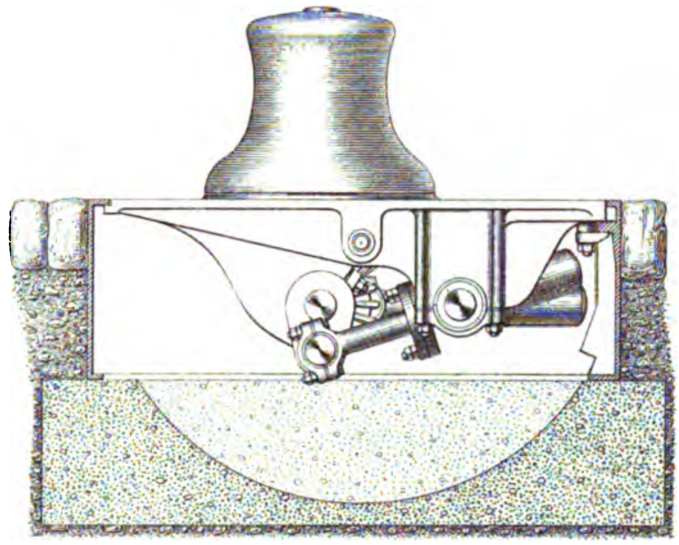
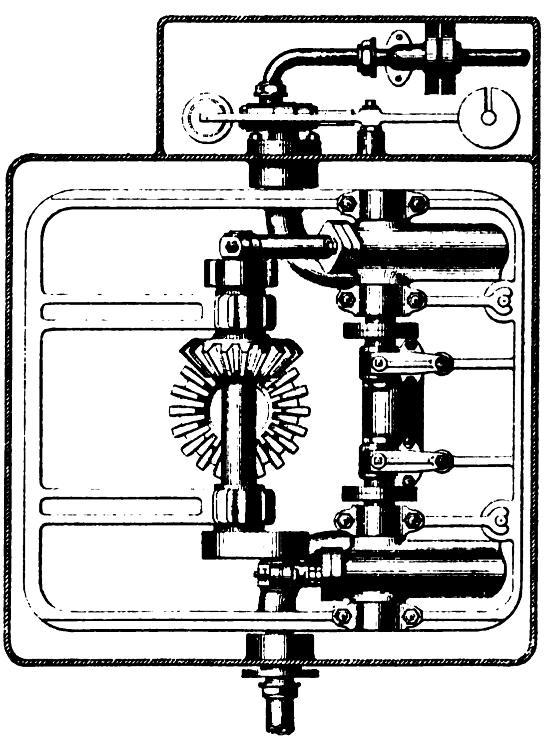
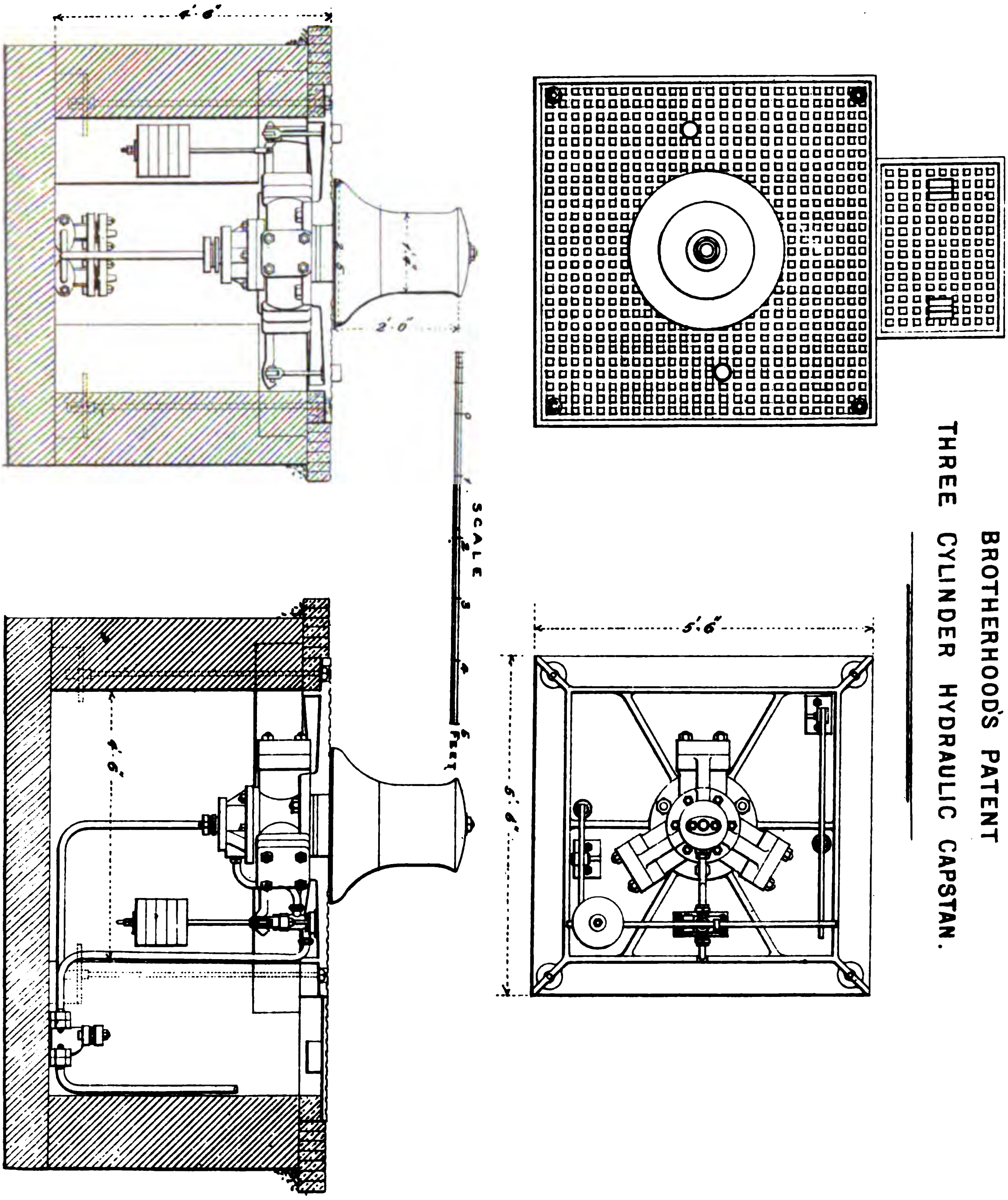
HYDRAULIC CAPSTAN





F. COLYER, M.I.C.E.



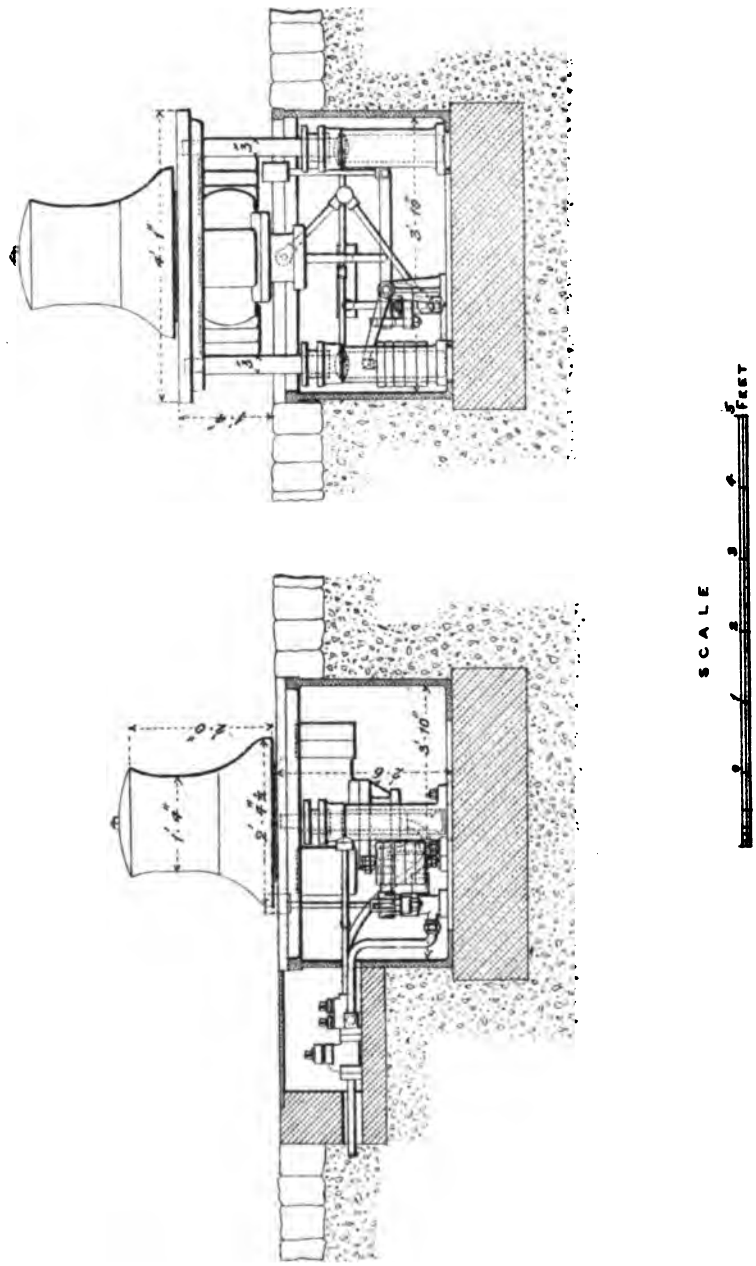
BROTHERHOOD'S PATENT

THREE CYLINDER HYDRAULIC CAPSTAN.

F. COLYER, M.I.C.E.

3 CYLINDER HYDRAULIC CAPSTAN.

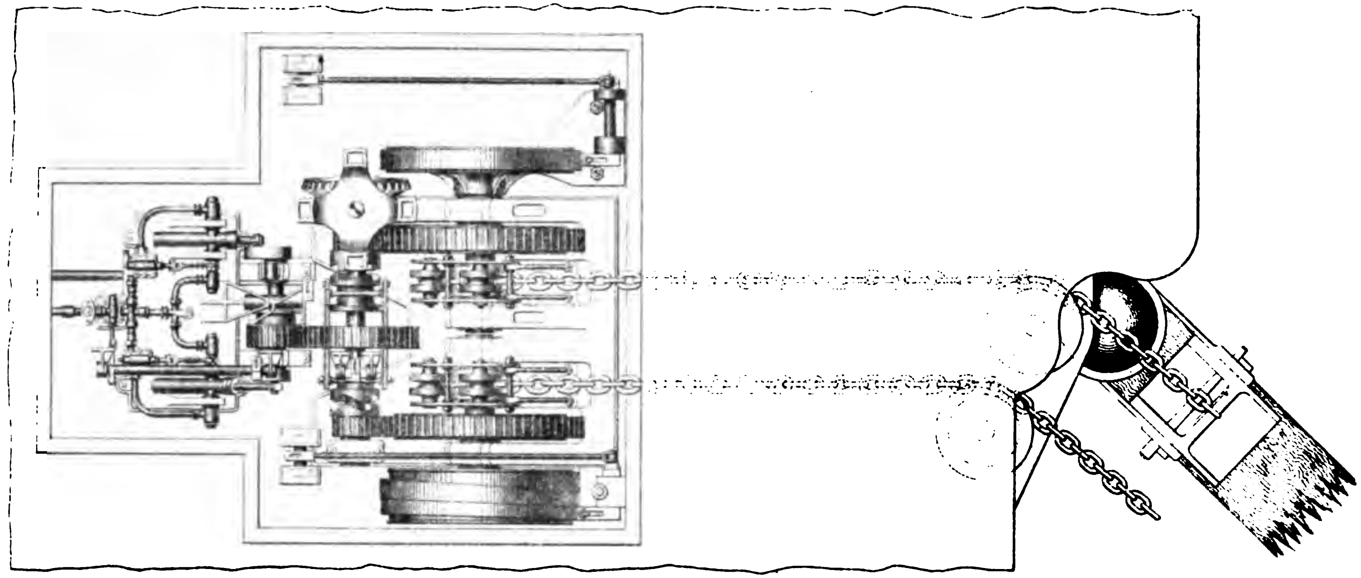
ELLINGTONS' PATENT.

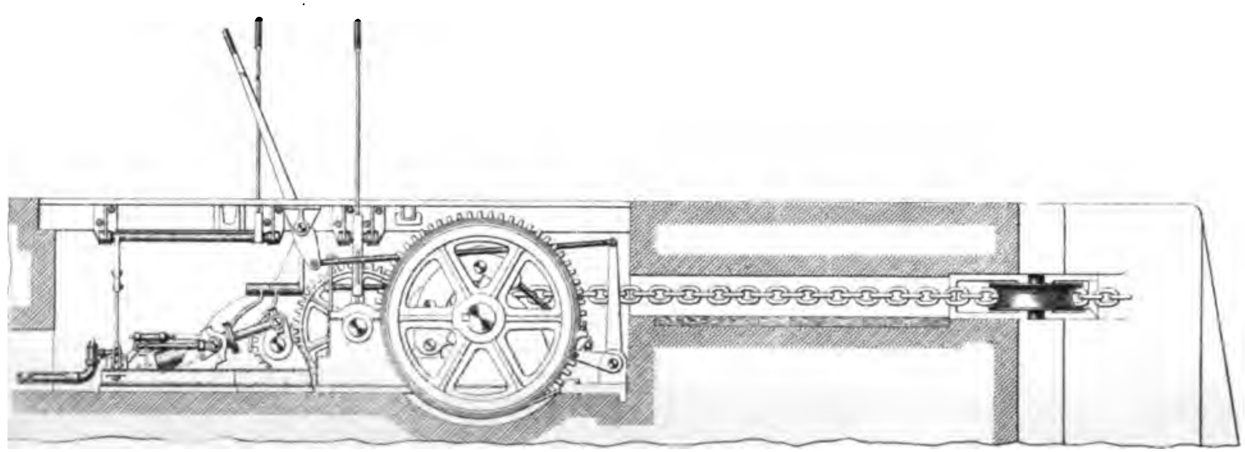


F. COLYER, M.I.C.E.

HYDRAULIC APPARATUS FOR DOCK GATES.

BY SIR W. G. ARMSTRONG & C°.

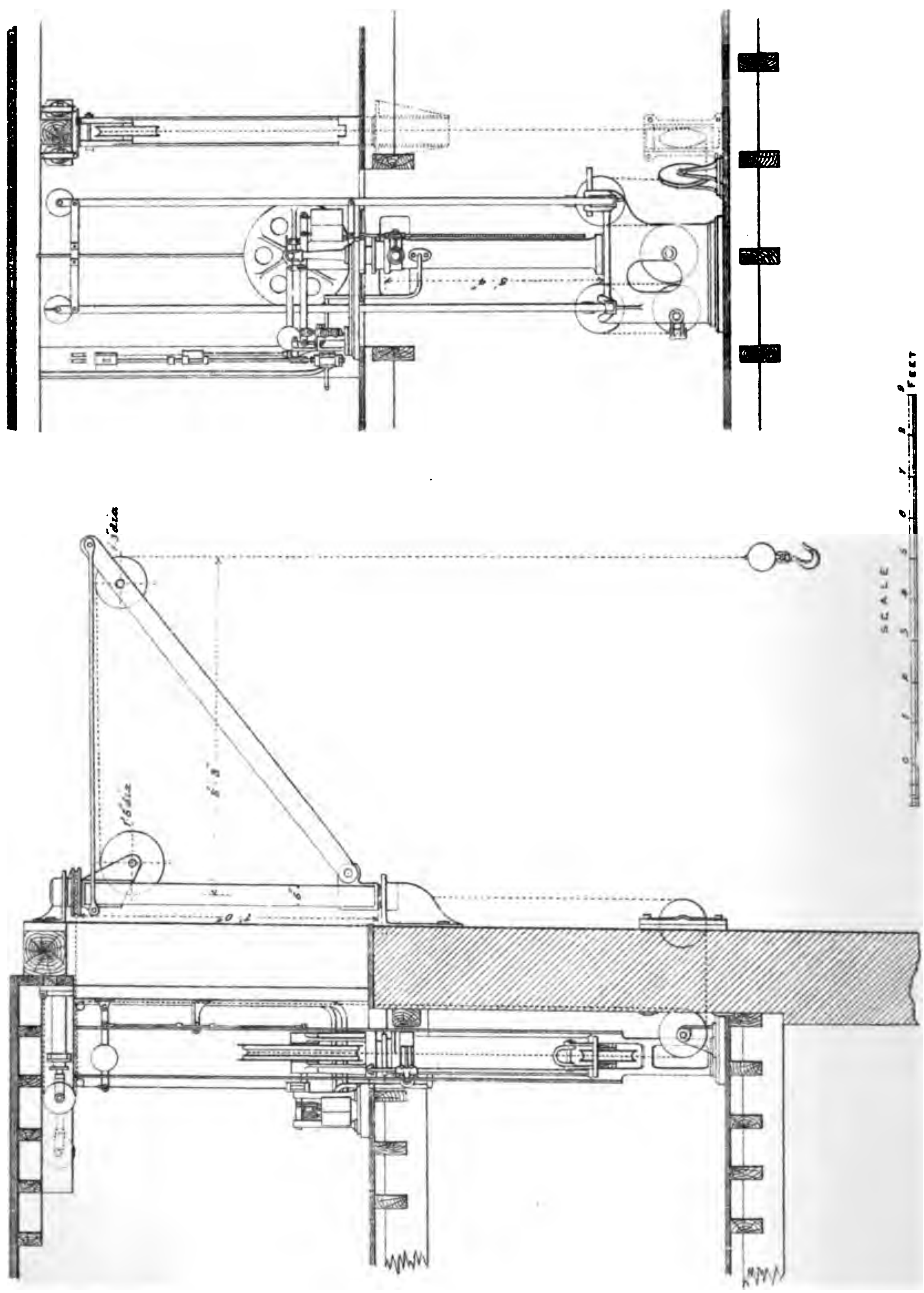




E. COLYER, M.I.C.E.

DOUBLE POWER HYDRAULIC WAREHOUSE CRANE.

JOHNSON & ELLINGTONS PATENT.



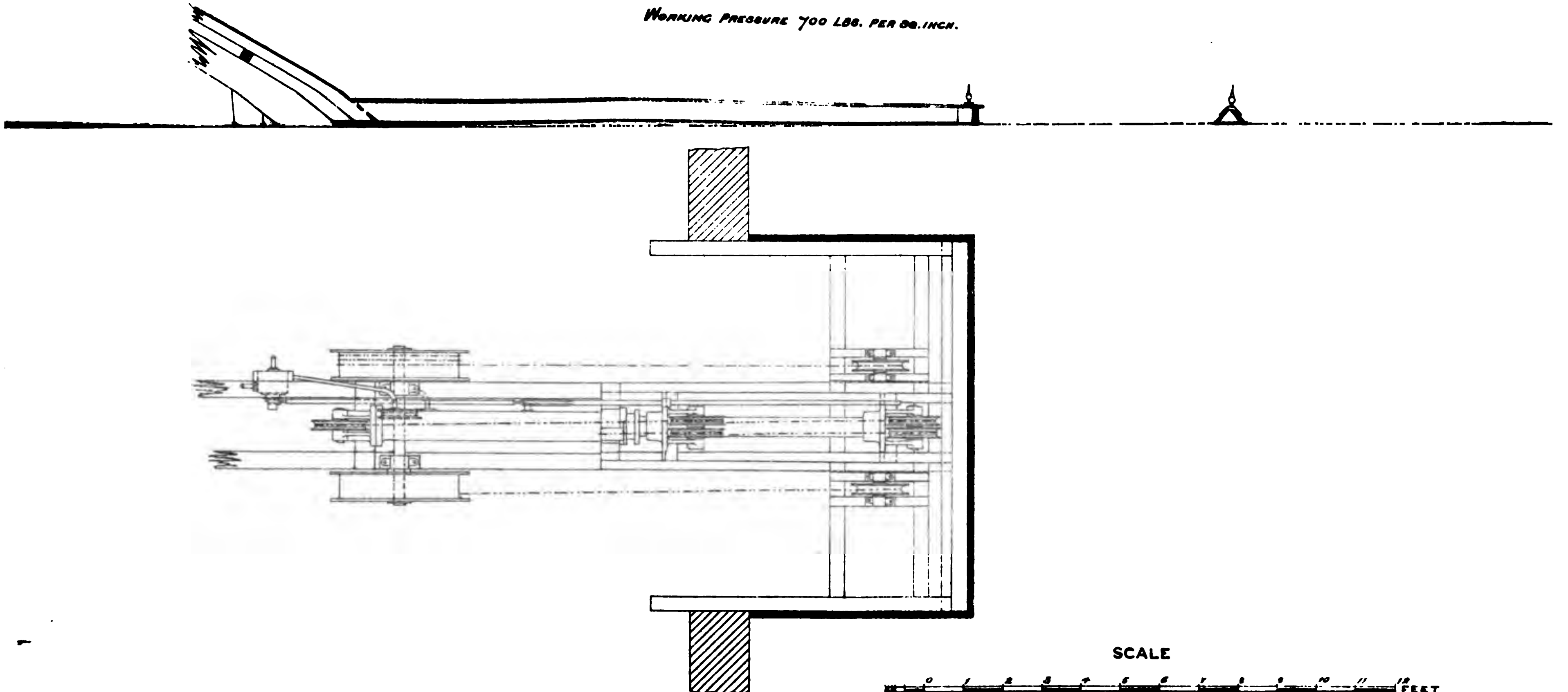
E. COLYER, M.I.C.E.

DRAWING No. 13.

7 CWT. DOUBLE CHAIN SACK HOIST.

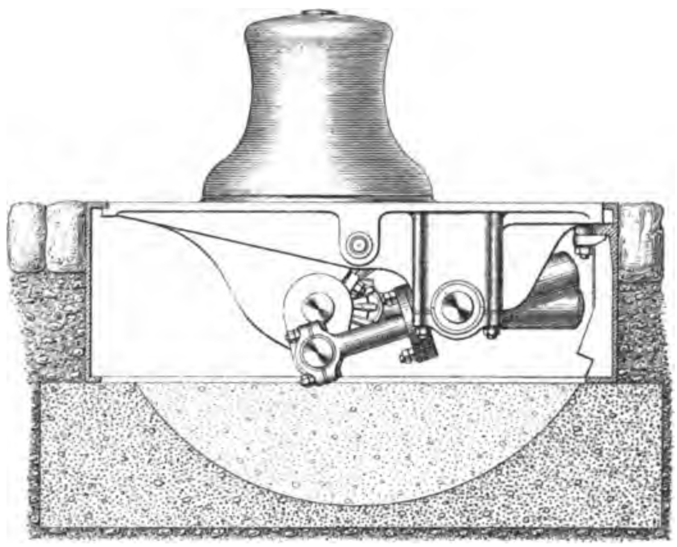
BY THE HYDRAULIC ENGINEERING COMPANY. CHESTER

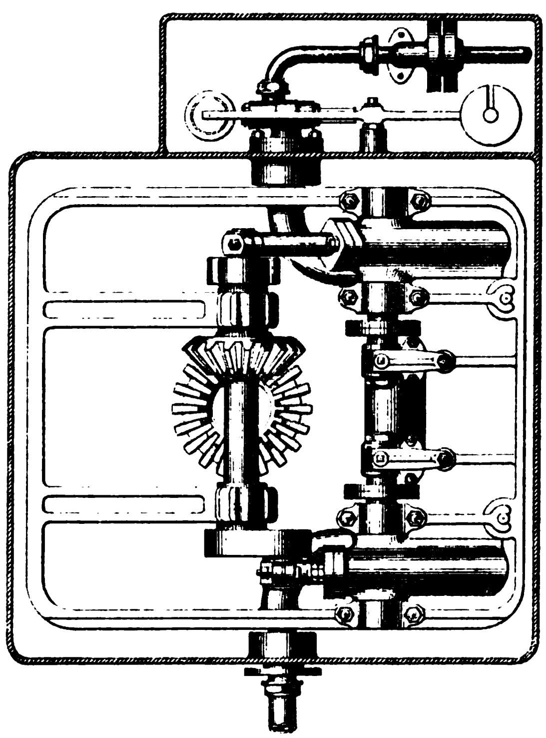
WORKING PRESSURE 700 LBS. PER SQ. INCH.



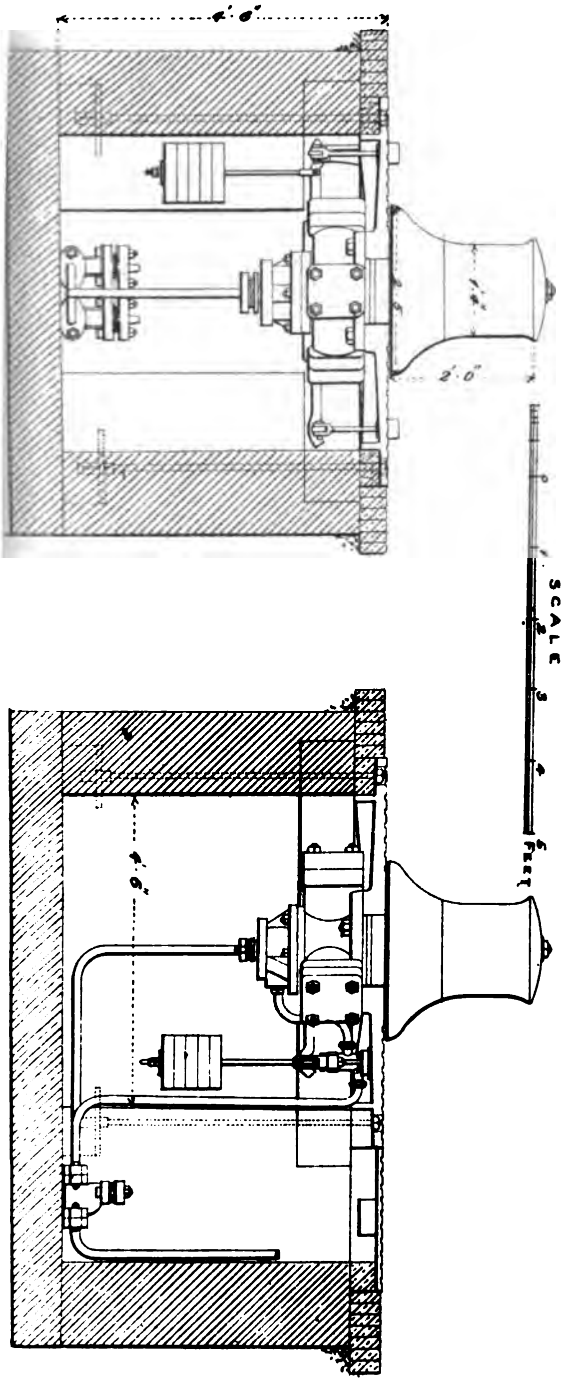
F. COLYER, M.I.C.E.

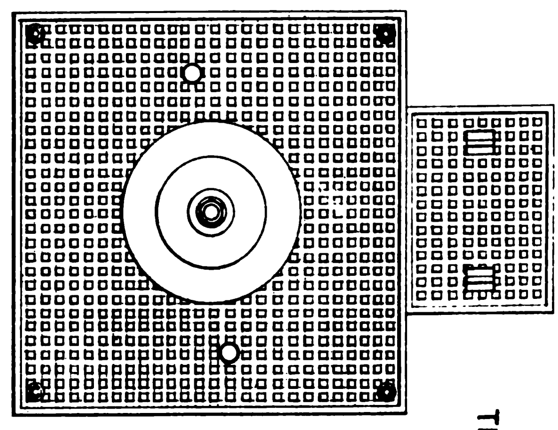
HYDRAULIC CAPSTAN

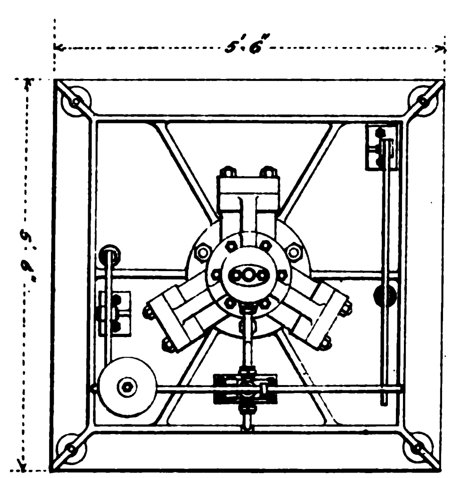




F. COLYER, M.I.C.E.







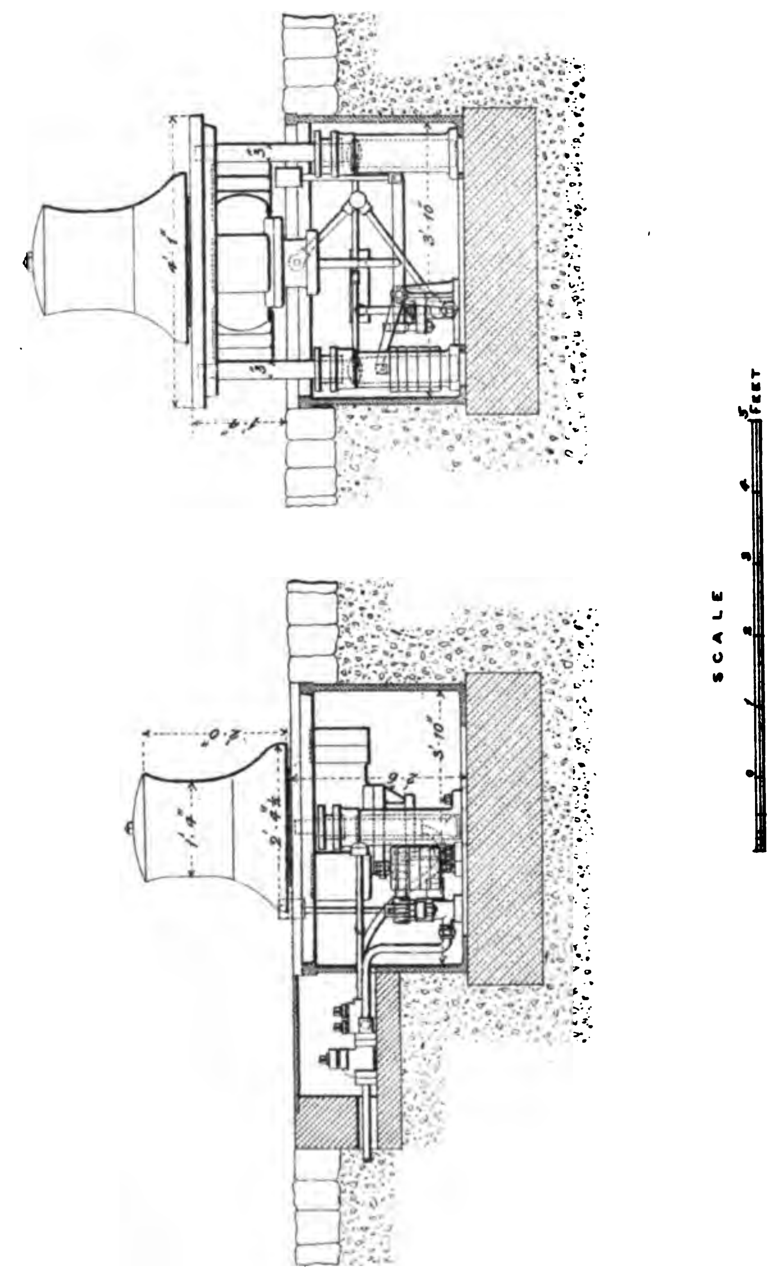
BROTHERHOOD'S PATENT

THREE CYLINDER HYDRAULIC CAPSTAN.

F. COLYER, M.I.C.E.

3 CYLINDER HYDRAULIC CAPSTAN.

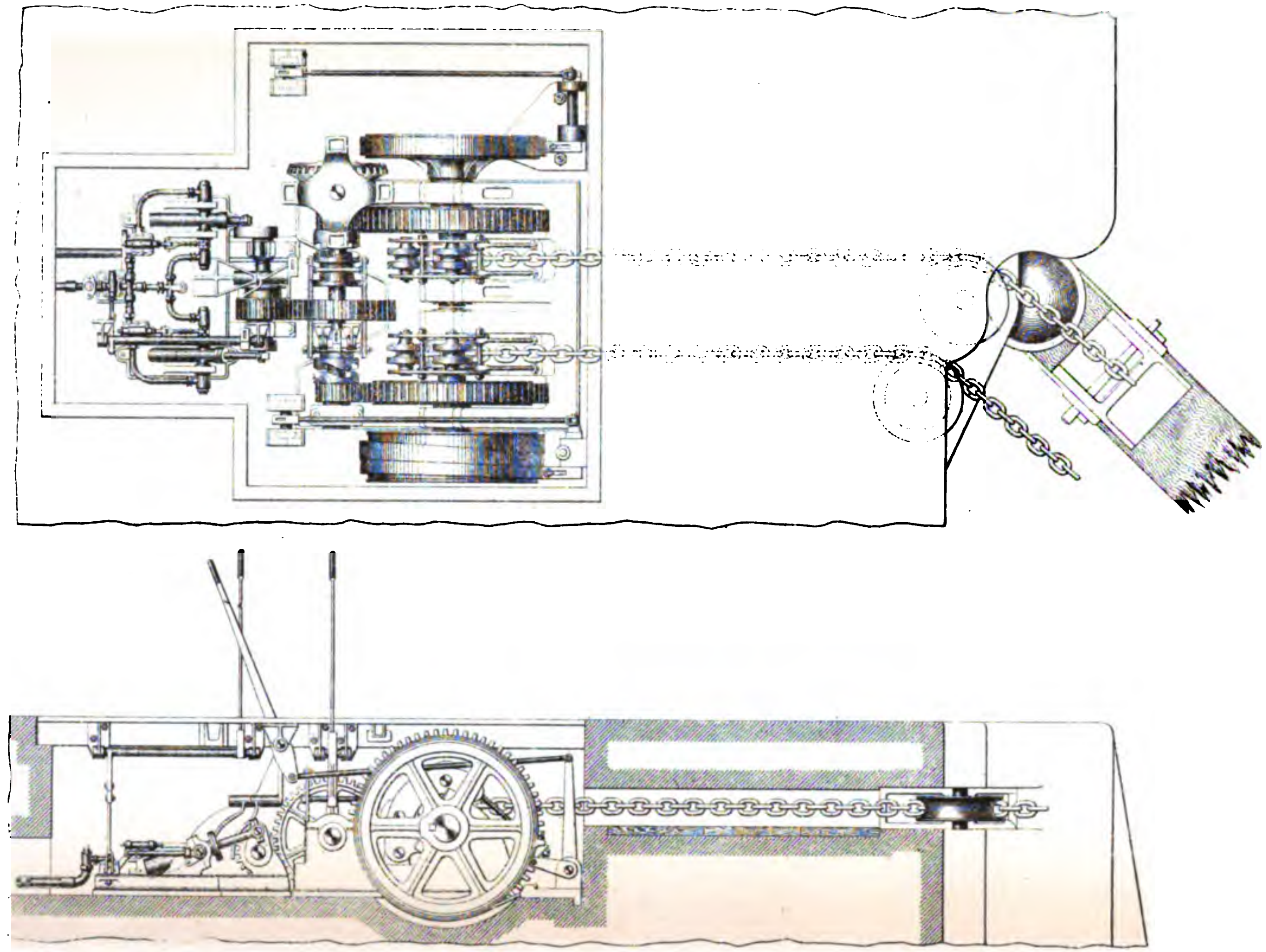
ELLINGTONS' PATENT.



F. COLYER, M.I.C.E.

HYDRAULIC APPARATUS FOR DOCK GATES.

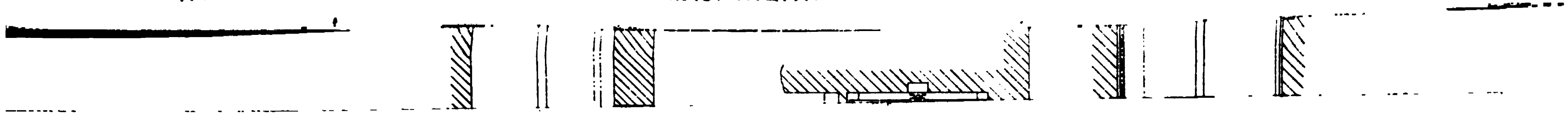
BY SIR W. G. ARMSTRONG & C^{o}.



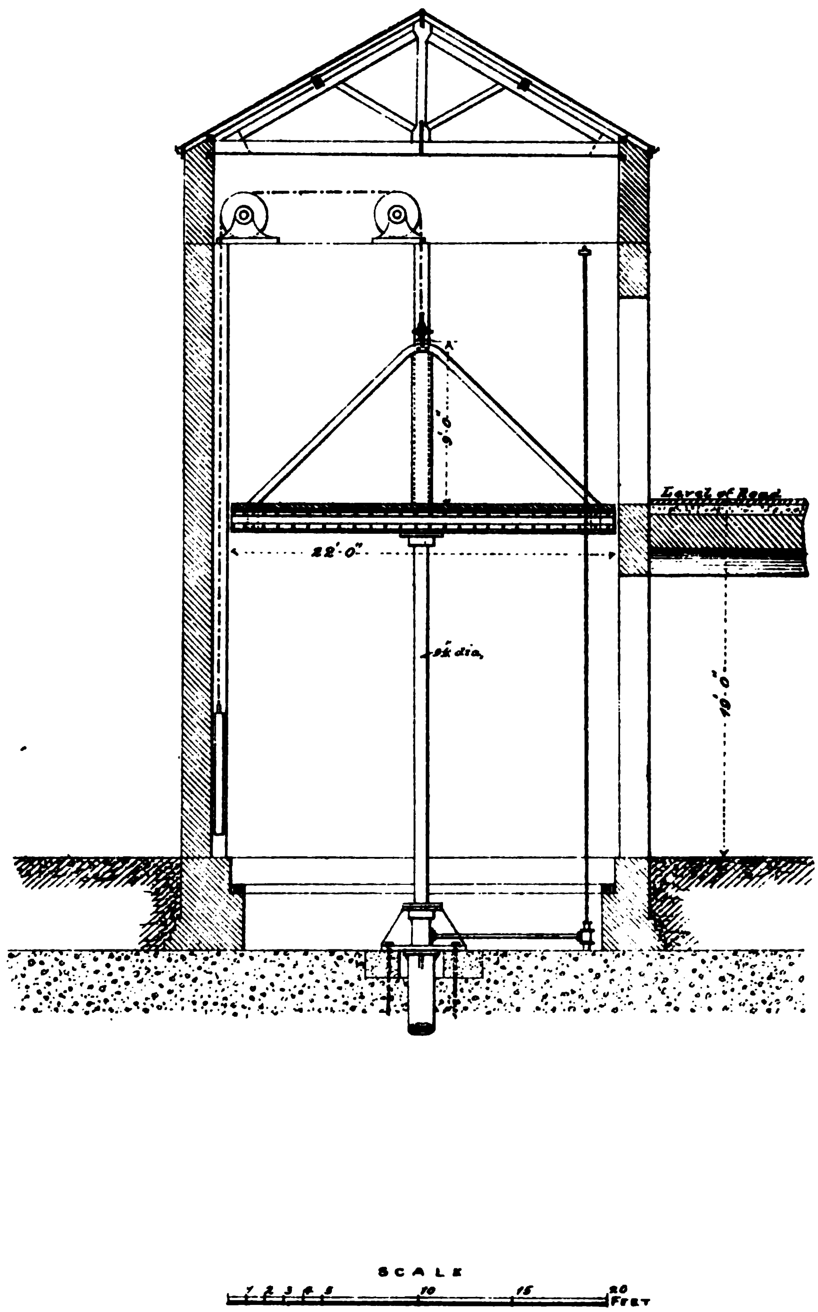
F. COLYER, M.I.C.E.

HYDRAULIC LIFTING AND PRESSING MACHINERY.

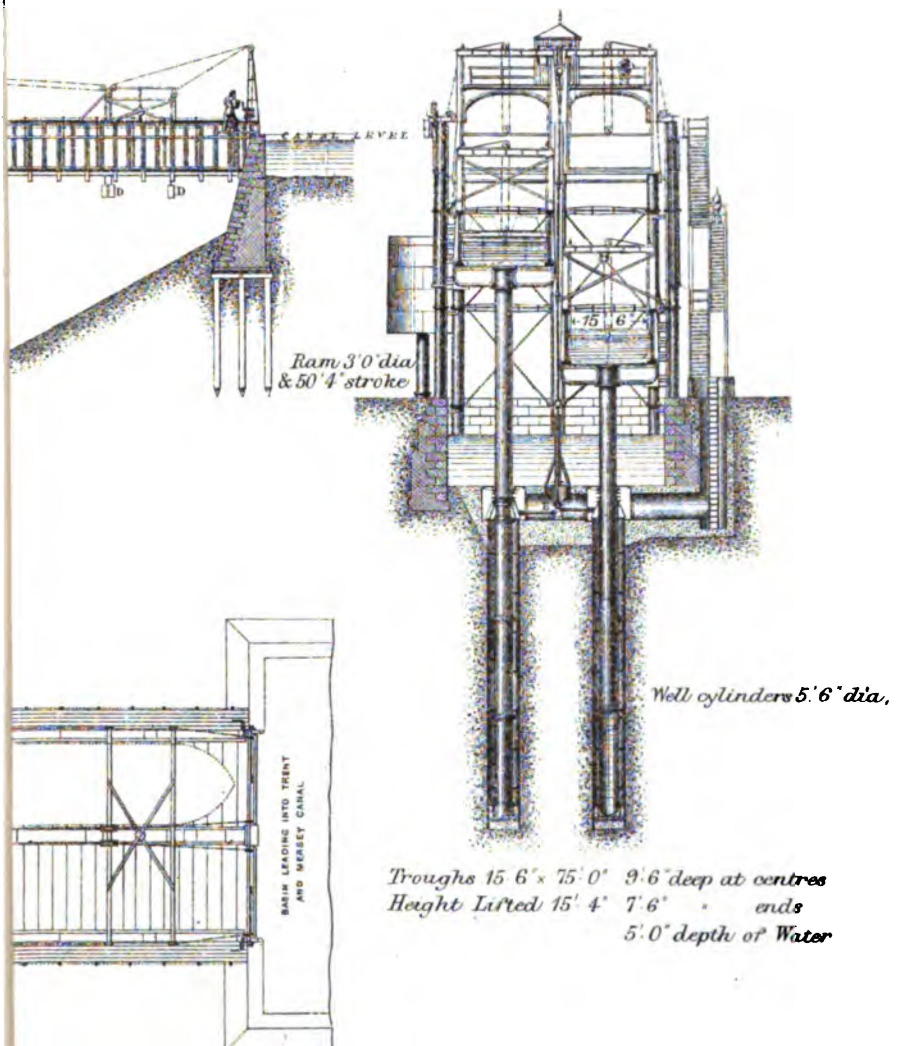
DRAWING No. 22.



HYDRAULIC WAGON HOIST.



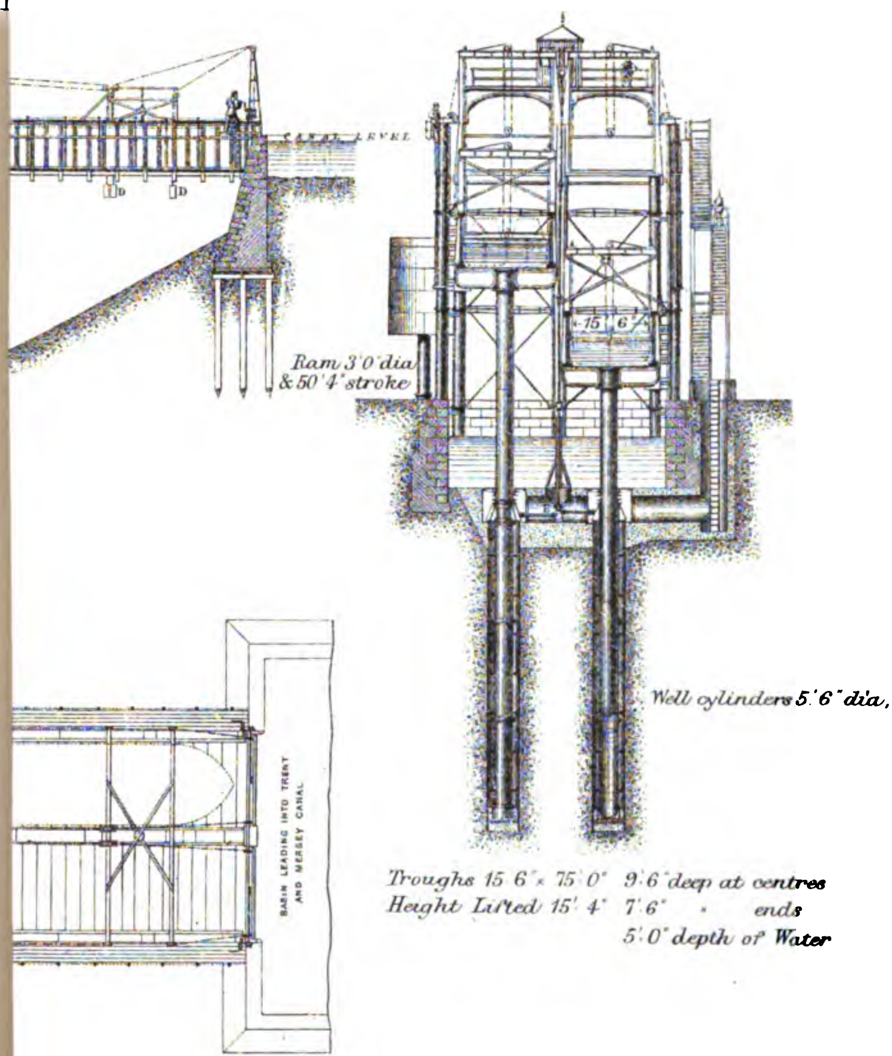
F. COLYER, M.I.C.E.


CANAL LEVEL
D
D
15' 6"
Ram 3' 0" dia & 50' 4" stroke
Well cylinders 5' 6" dia,
BASIN LEADING INTO TRENT AND MERSEY CANAL
Troughs 15' 6" × 75' 0"   9' 6" deep at centres
Height Lifted 15' 4"   7' 6"   "   ends
5' 0" depth of Water

F. C

HYD

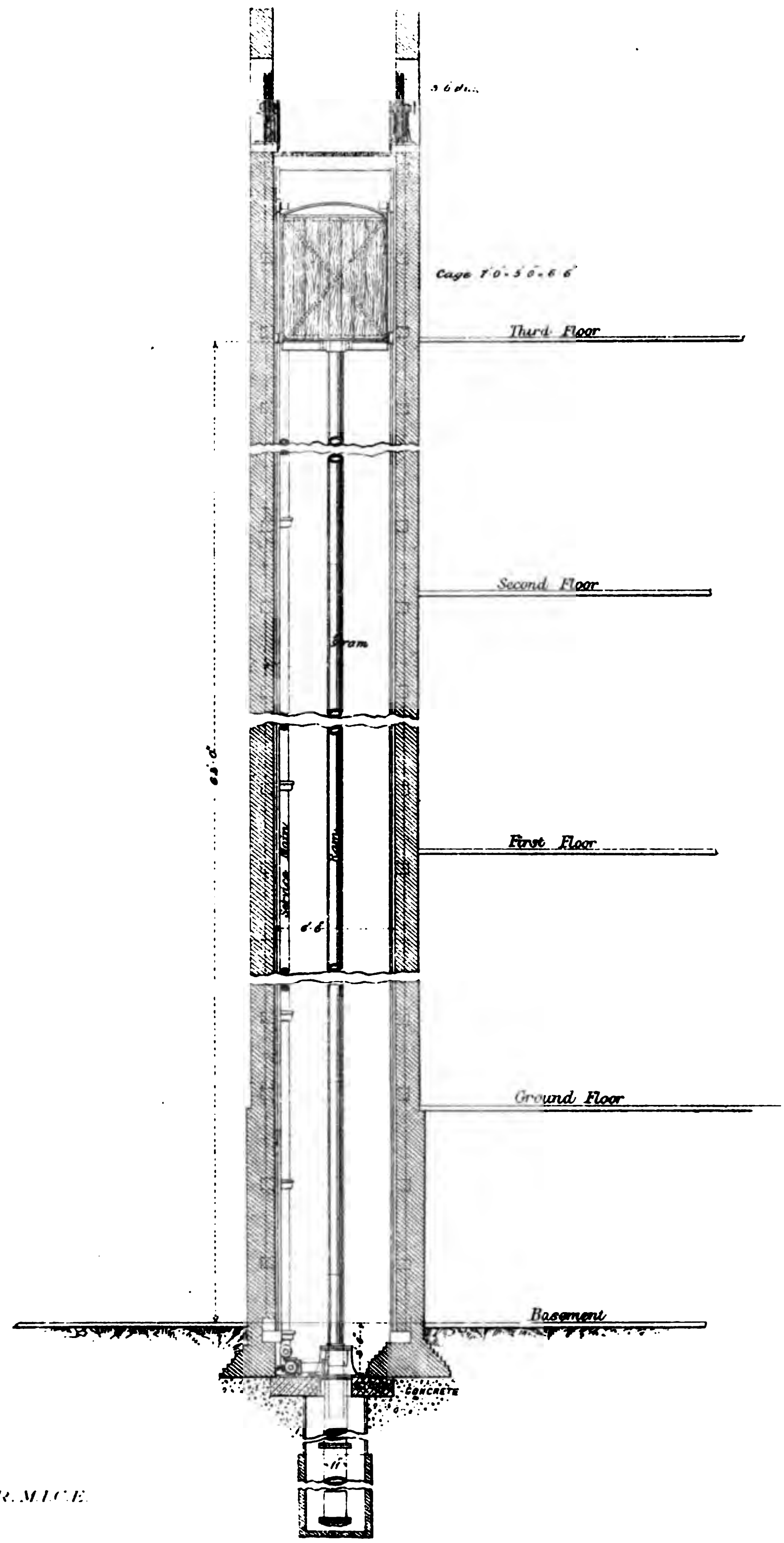
DRAWING No. 20.



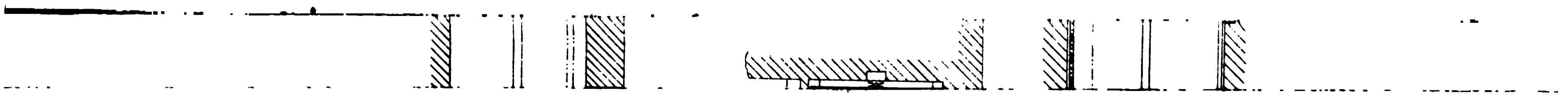
F. C

 DRAWING No 21.

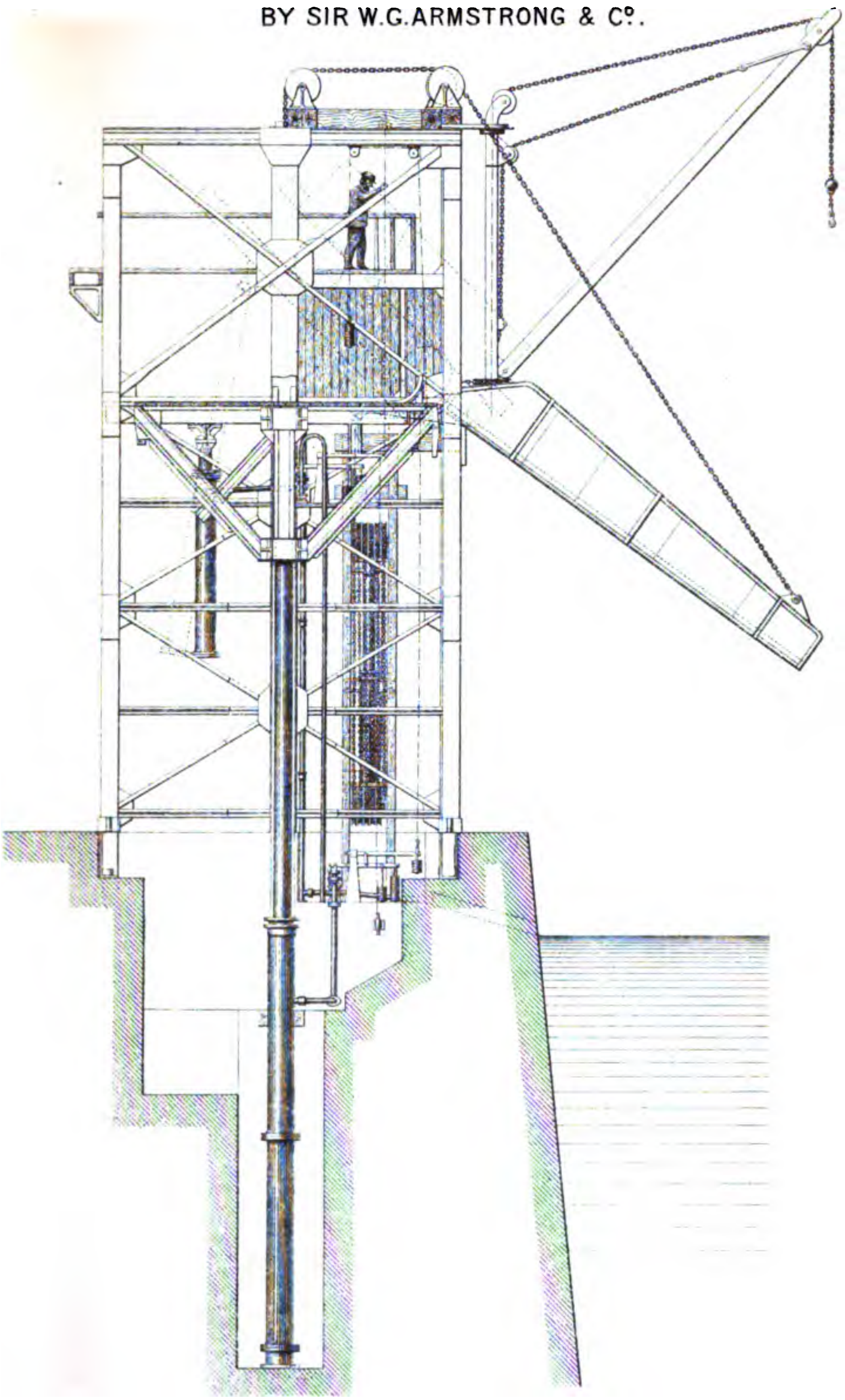
HYDRAULIC PASSENGER LIFT.



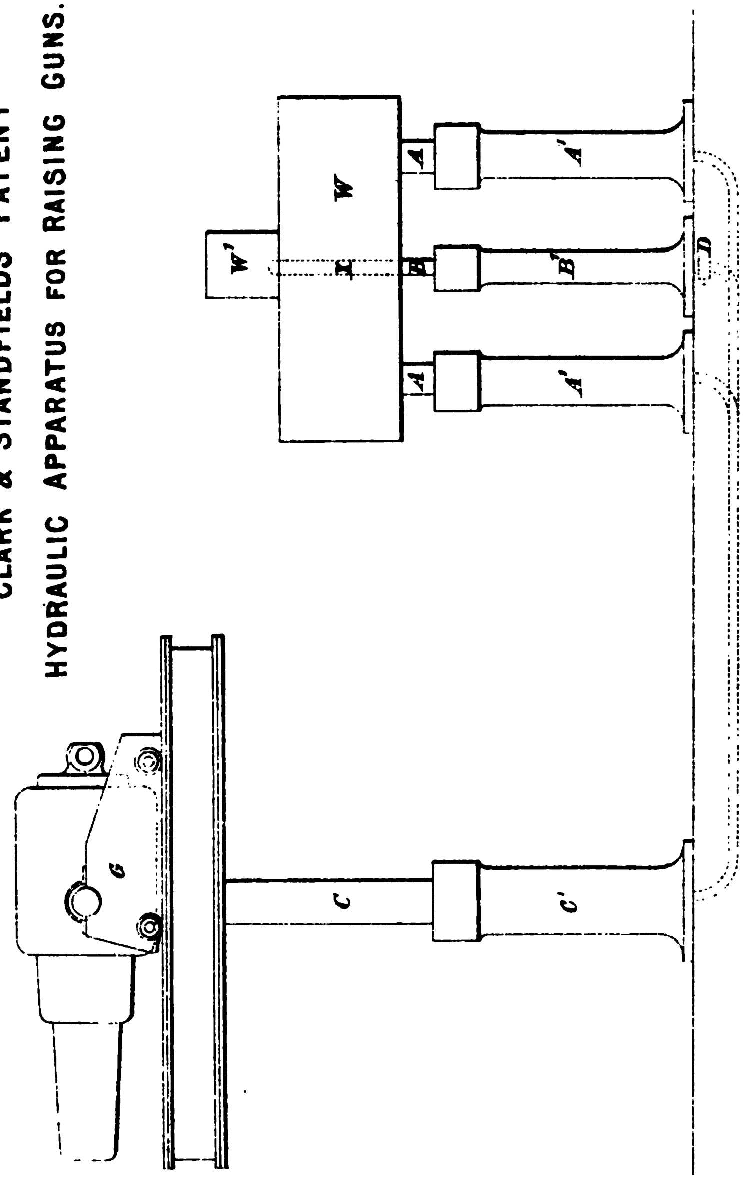
F. COLYER, M.I.C.E.



HYDRAULIC COAL DISCHARGING APPARATUS.
BY SIR W.G. ARMSTRONG & Cº.

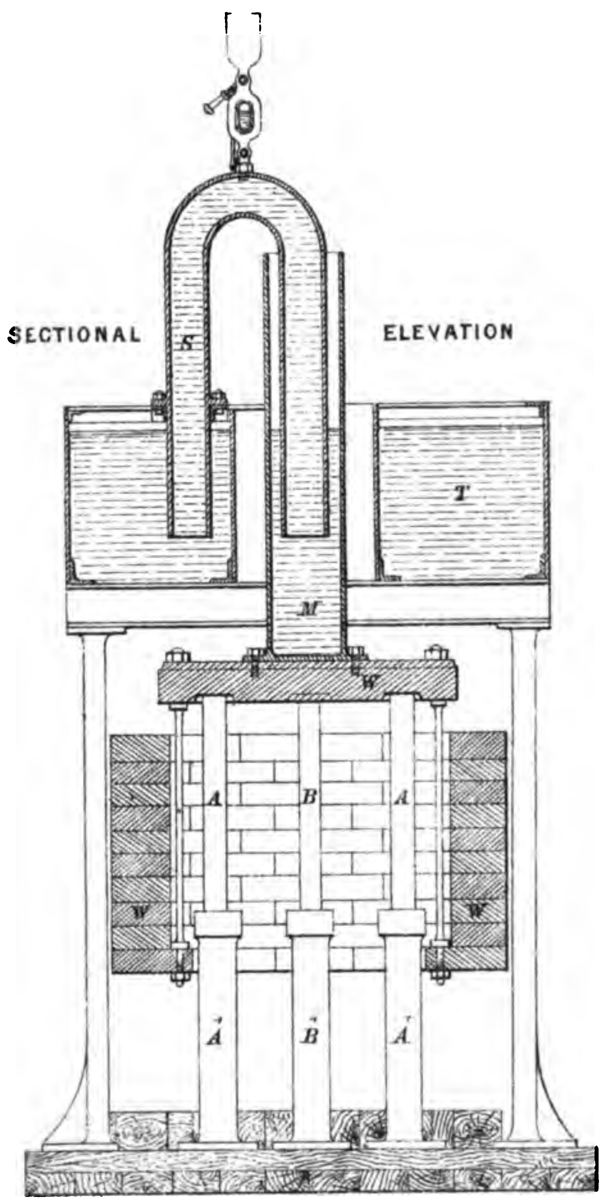


F. COLYER. M.I.C.E.



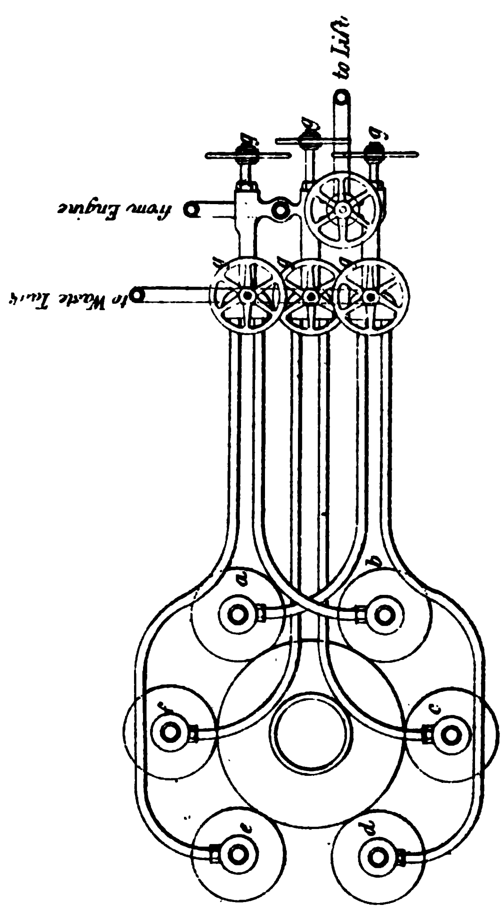
CLARK & STANDFIELD'S PATENT
HYDRAULIC APPARATUS FOR RAISING GUNS.

CLARK & STANDFIELD'S
PATENT HYDRAULIC DIFFERENTIAL ACCUMULATOR.



F. COLYER, M.I.C.E.

CLARK & STANDFIELD'S
PATENT HYDRAULIC DIFFERENTIAL ACCUMULATOR.

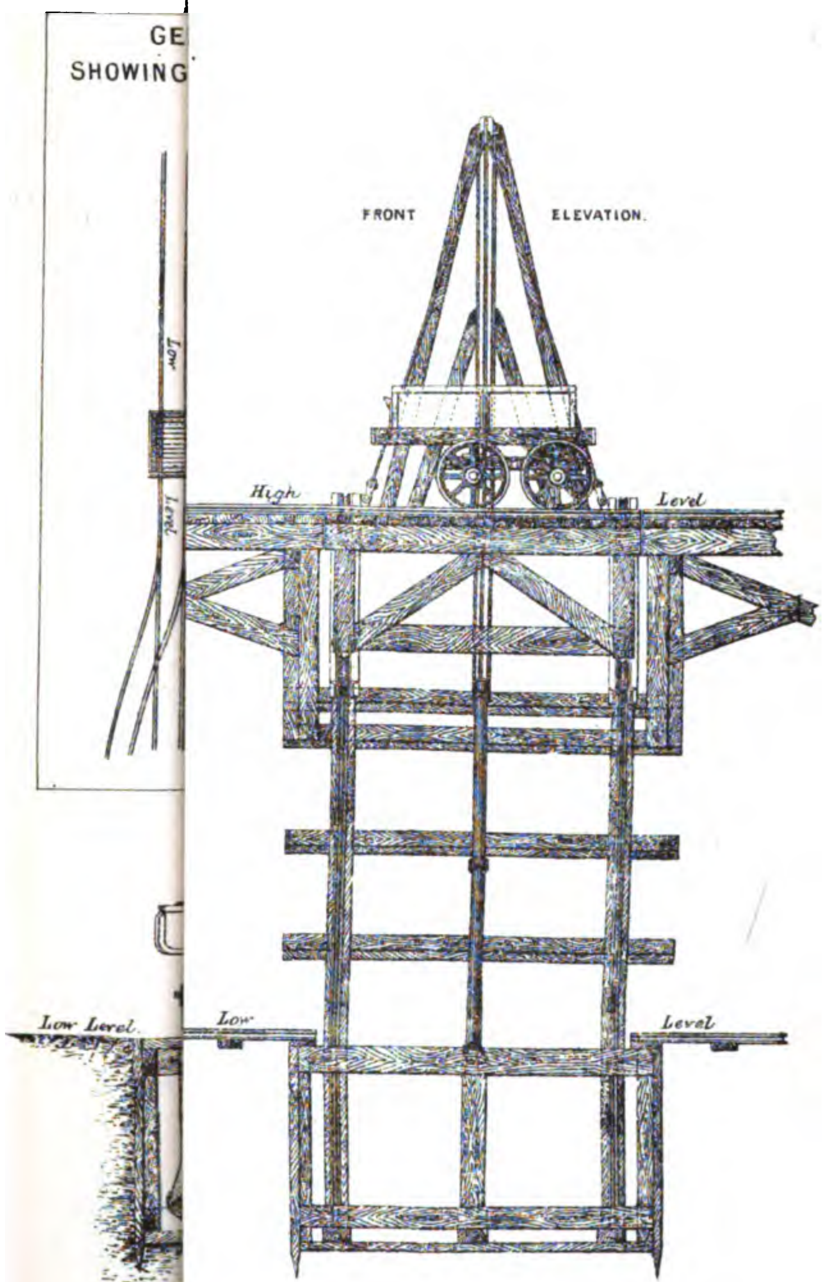


PLAN OF PIPES & VALVES.

F. COLYER, M.I.C.E.

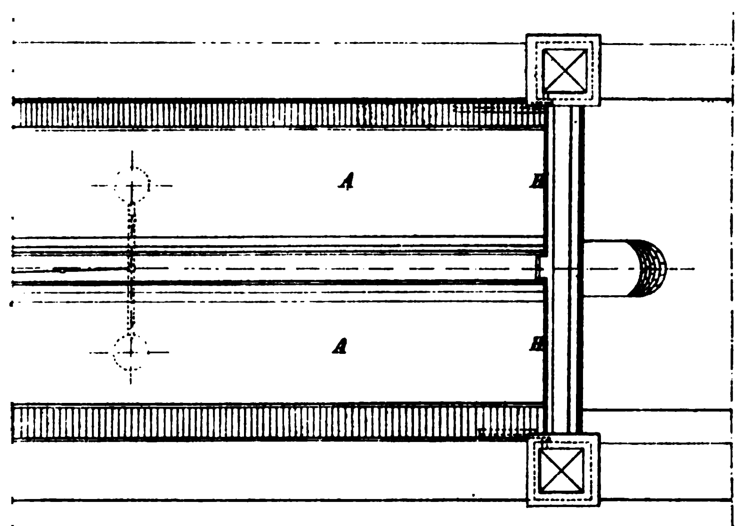
HYDRAULIC

DRAWING No. 27.

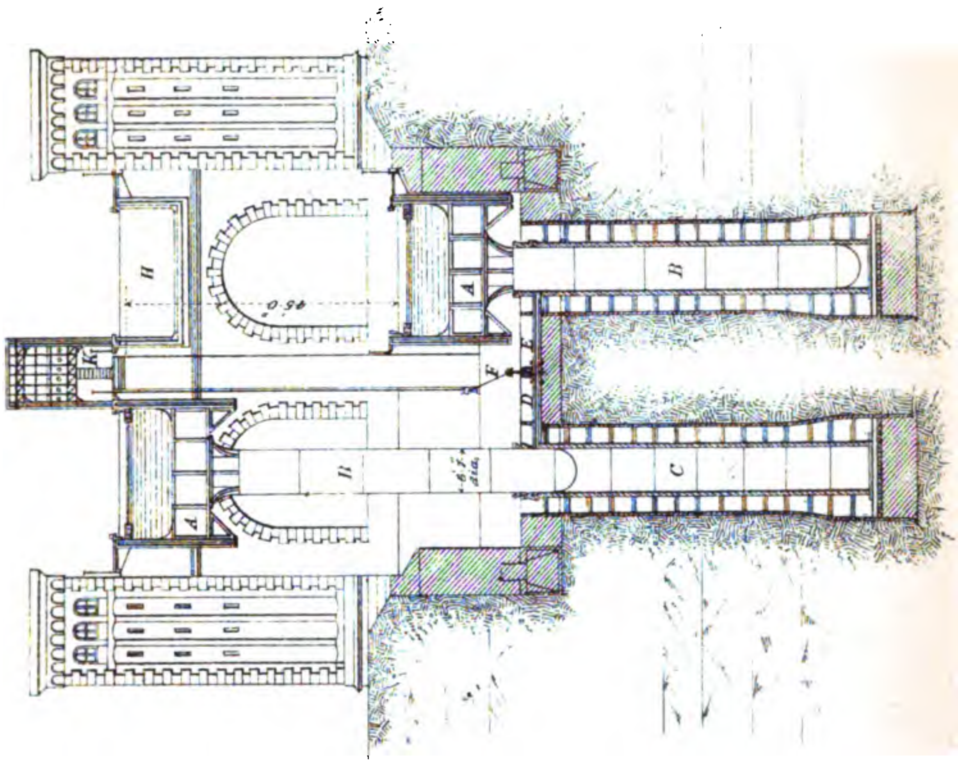


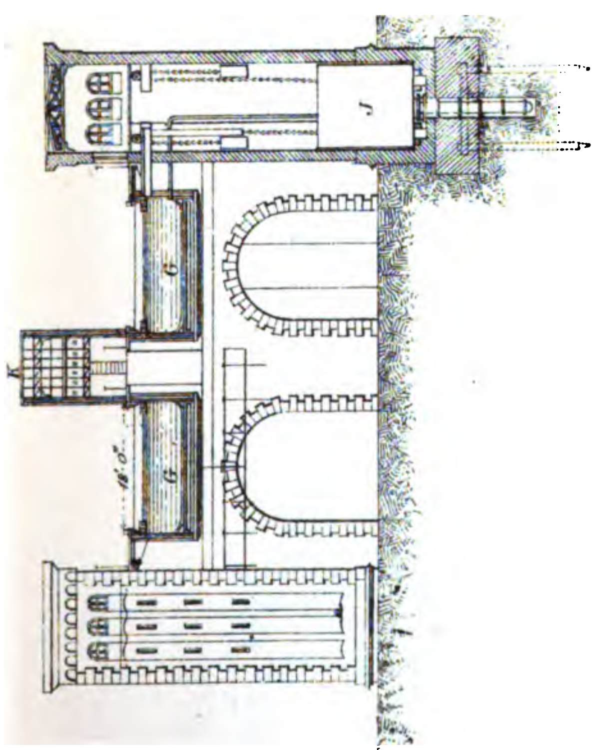
F. COLYER, M.I.C.E.

DRAWING Nº 31.



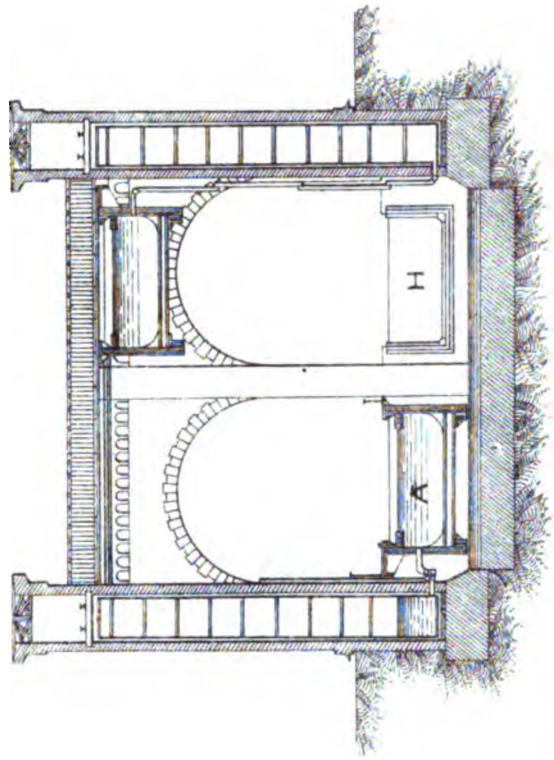
TRANSVERSE SECTION.



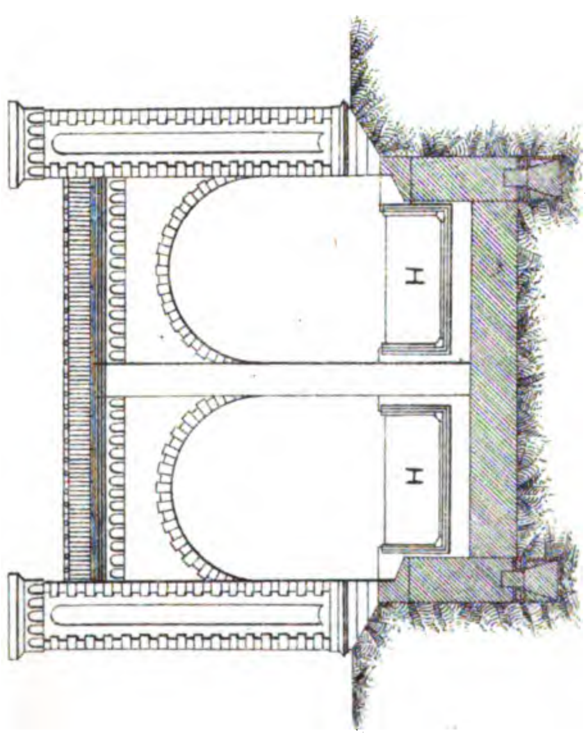


F. COLYER, M.I.C.E.

SECTION AT Z-Z



SECTION AT Y.Y.



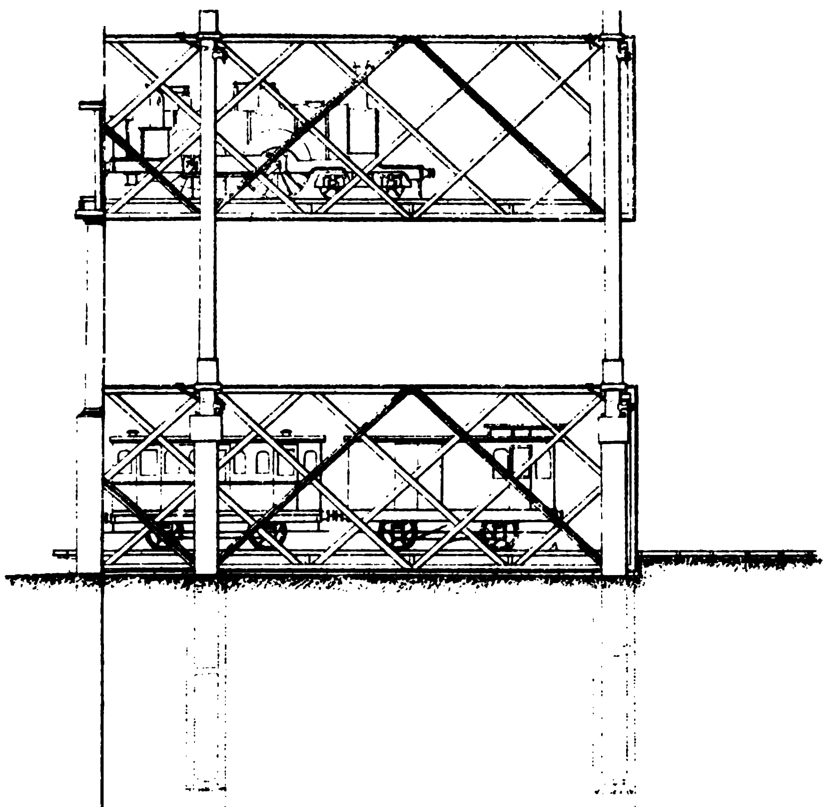
E. COLYER, M.I.C.E.

HYDRAULIC

DRAWING No. 36.

TS FOR

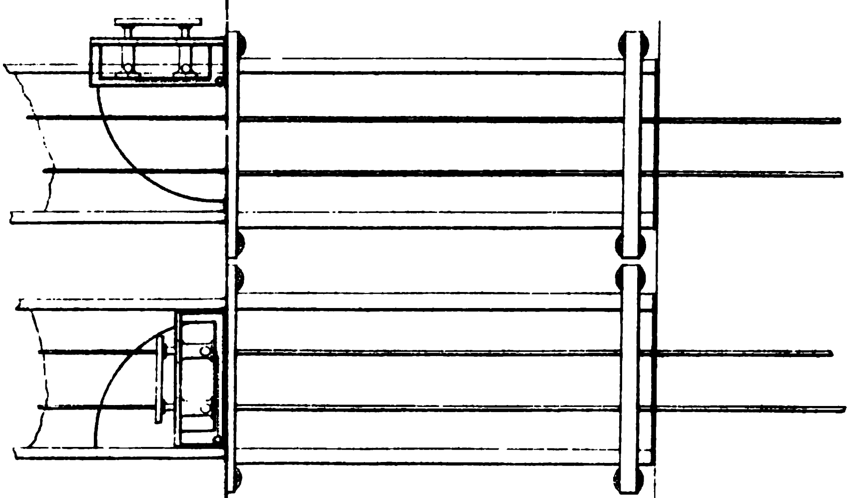
.



F. COLYER, M.I.C.

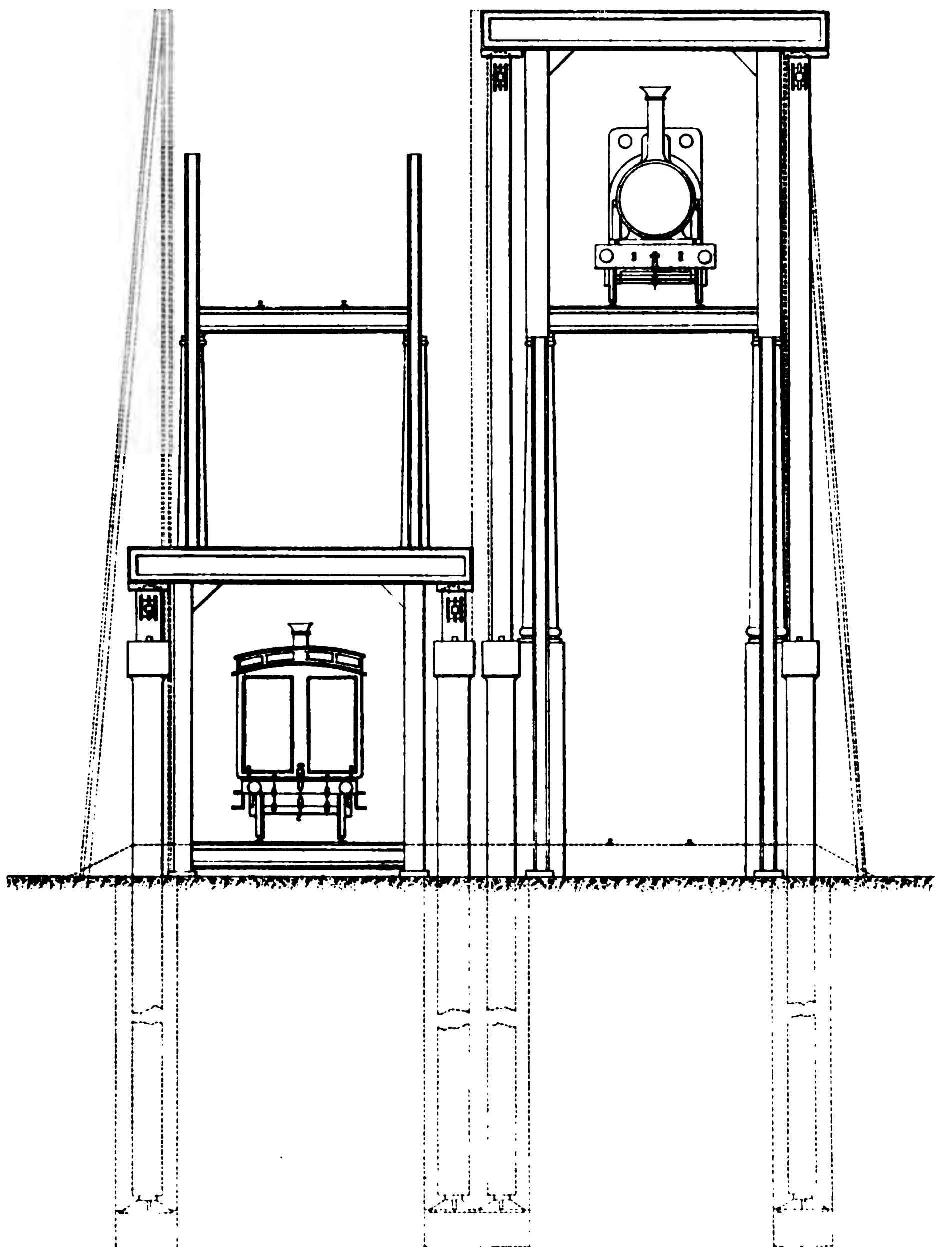
HYDRAULIC LIFT

DRAWING No. 37.



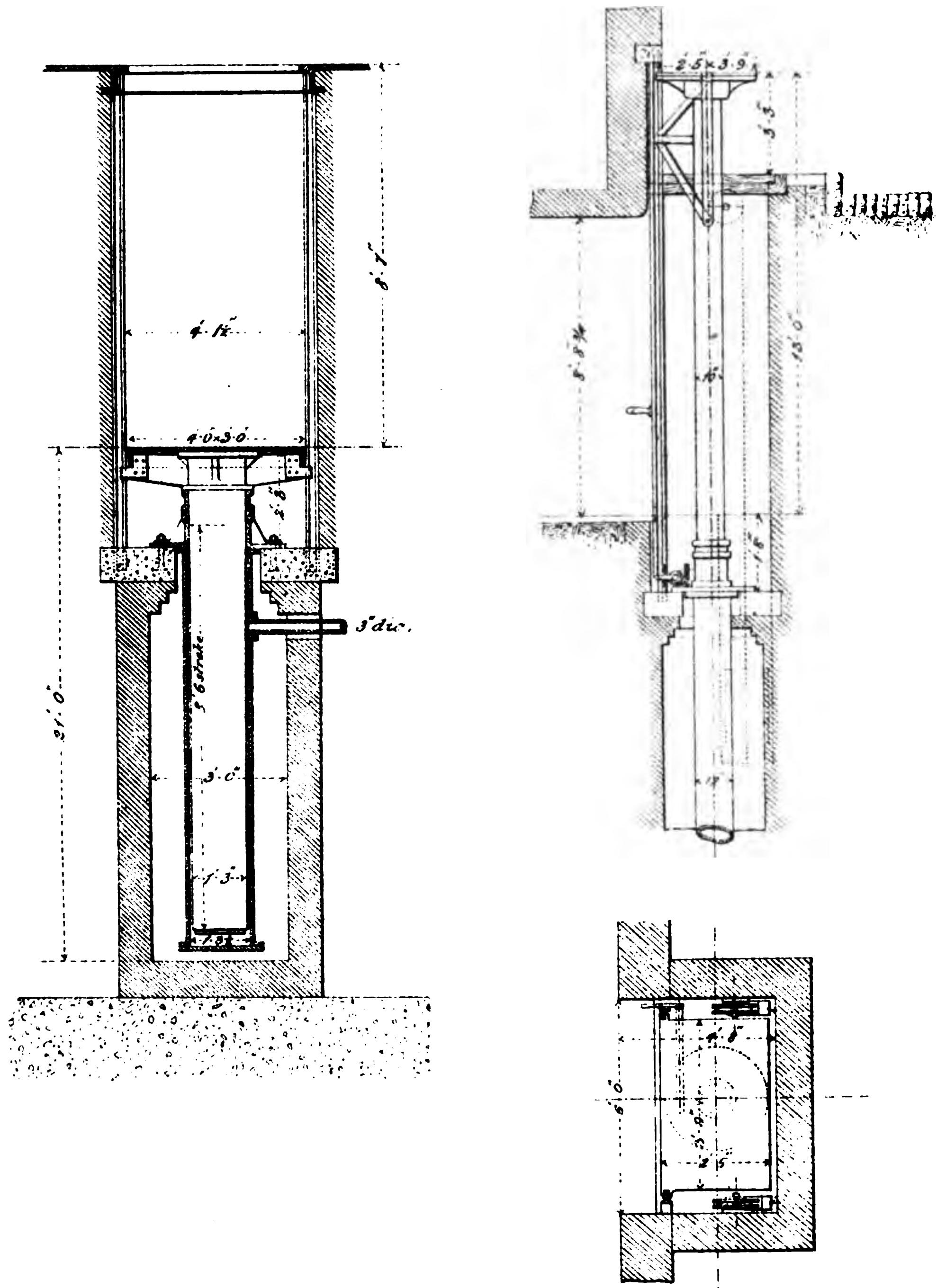
F. COLYER, M.I.C.E.

MESSRS CLARK & STANDFIELDS PATENT HYDRAULIC LIFTS FOR TRANSFERRING TRAINS TO DIFFERENT LEVELS.



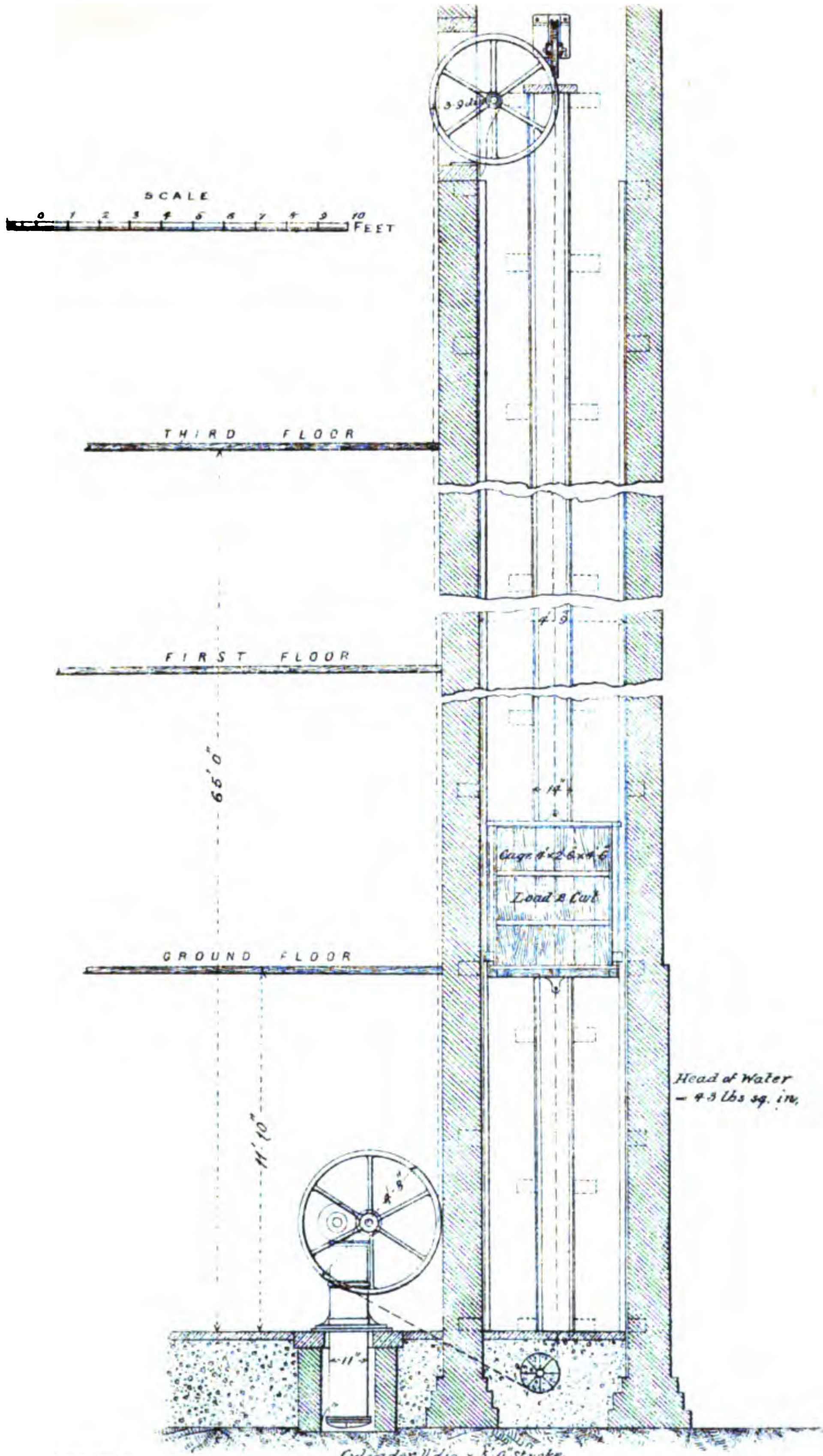
F. COLYER, M.I.C.E.

HYDRAULIC RAM LIFTS



F. COLYER, M.I.C.E.

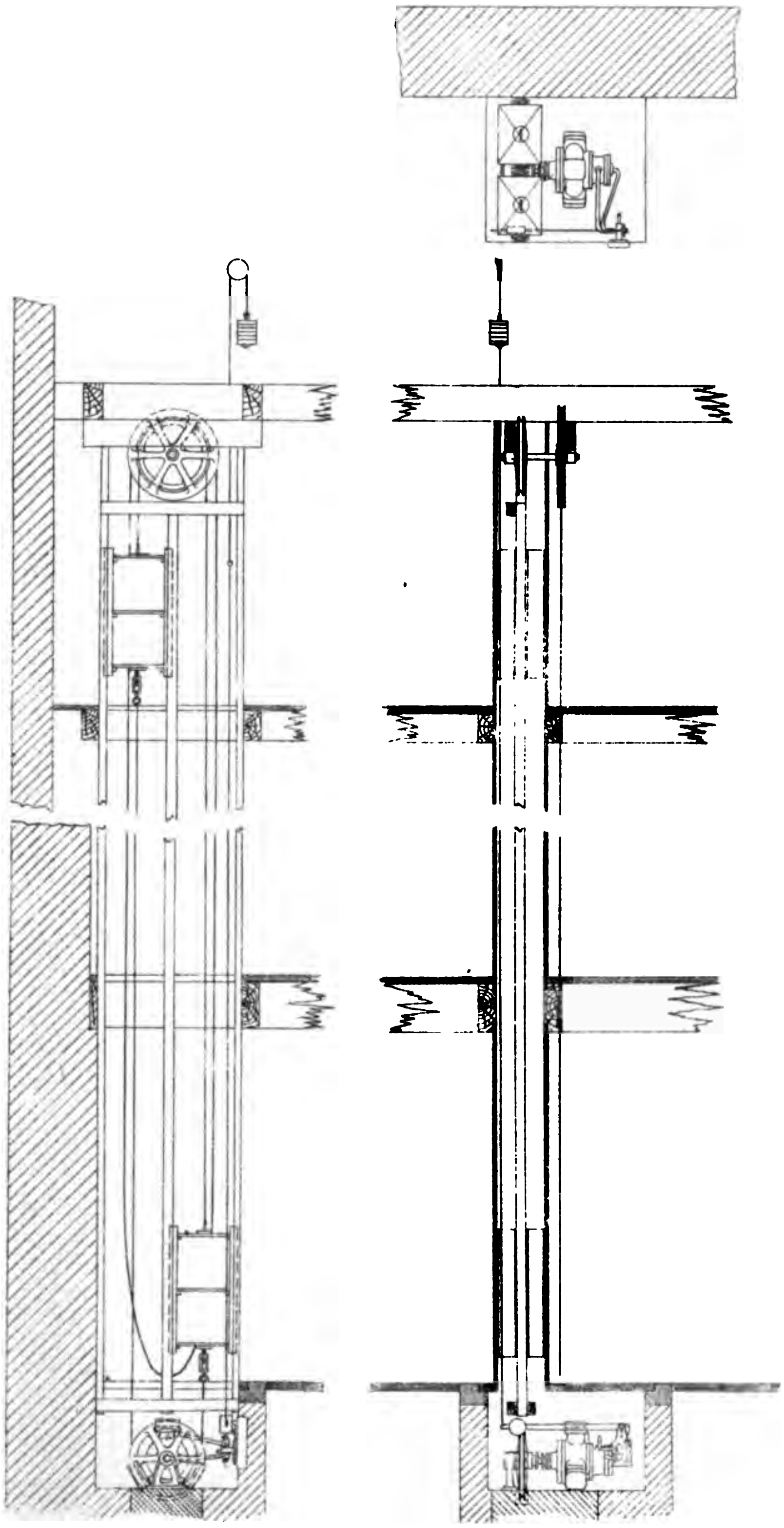
HYDRAULIC LIFT WORKED BY SHORT STROKE CYLINDER.



F. COLYER, M.I.C.E.

ELLINGTON'S IMPROVED HYDRAULIC PARCEL LIFT.

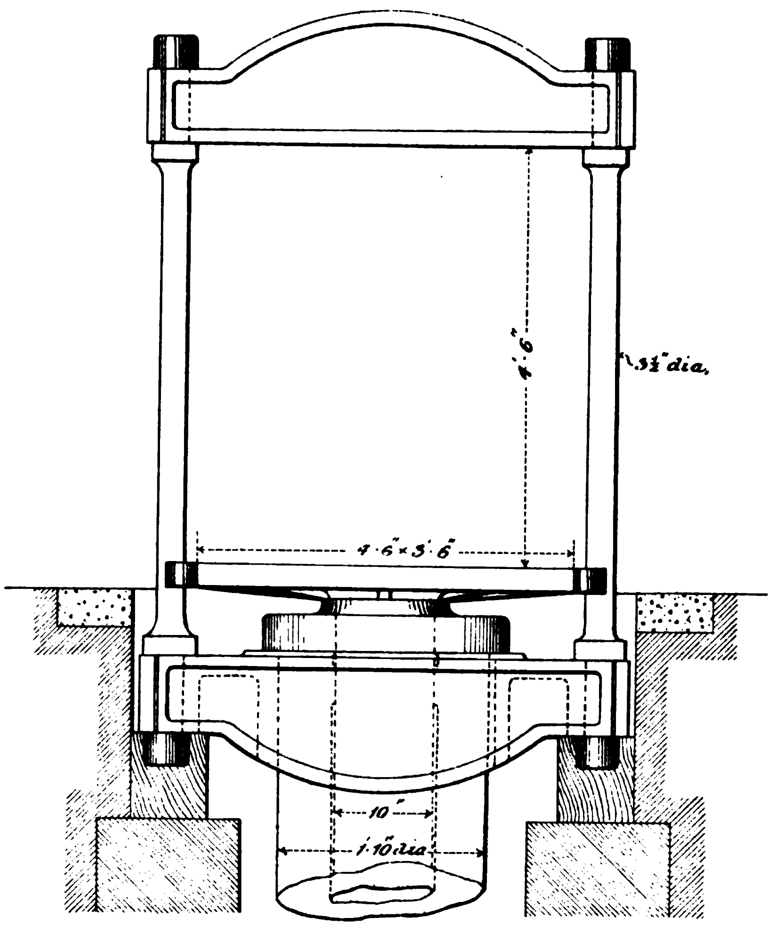
WORKING PRESSURE 700 LBS. PER SQ. INCH.



SCALE

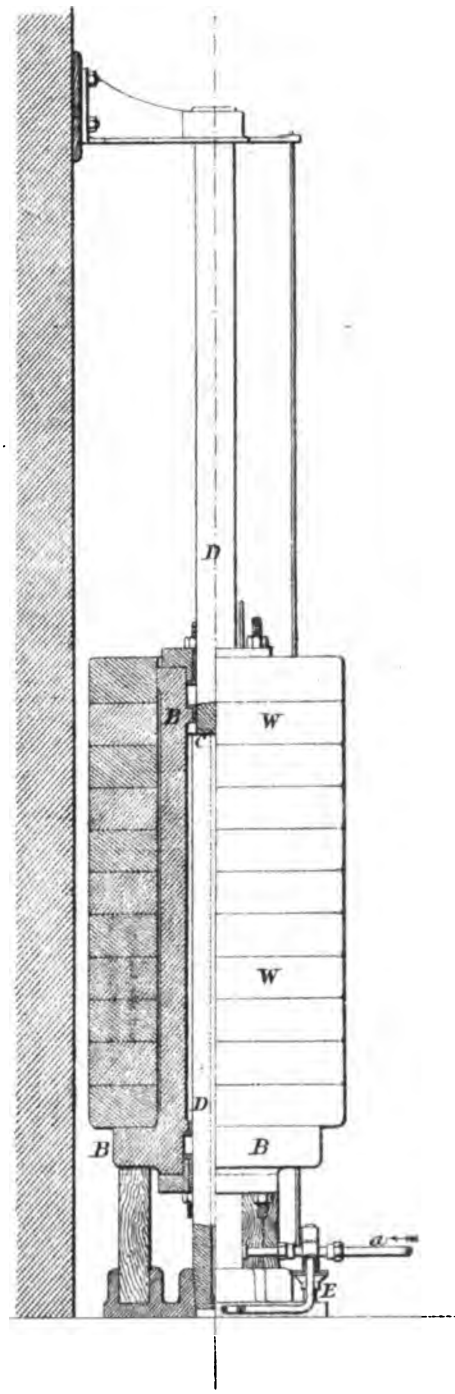
F. COLYER, M.I.C.E.

HYDRAULIC PRESS



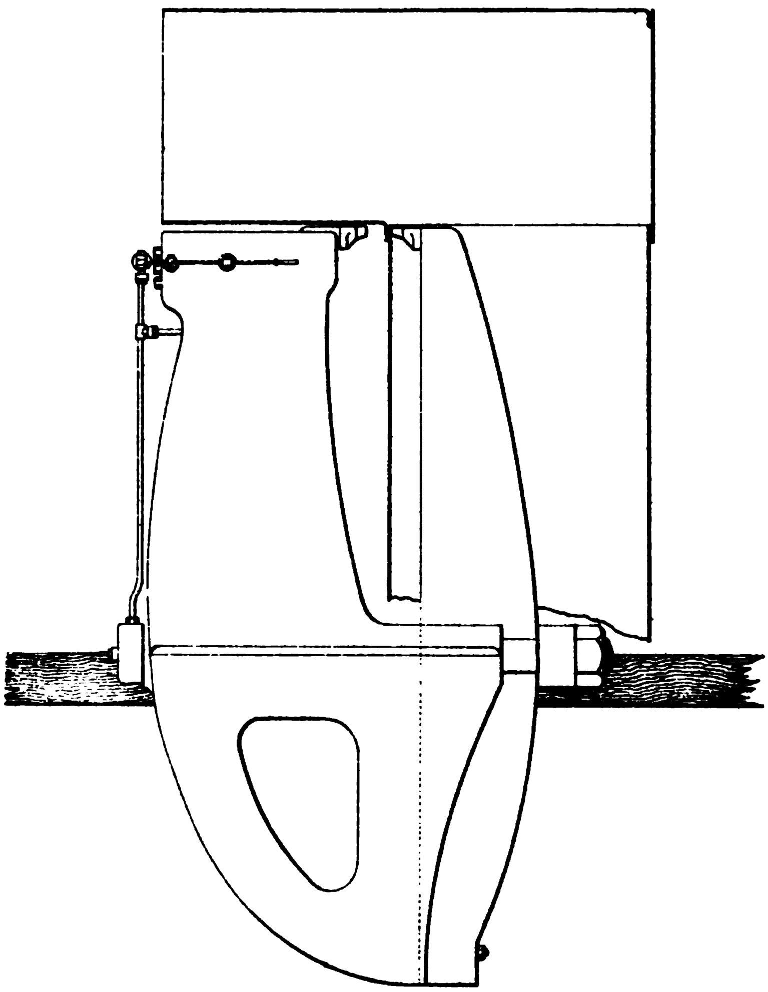
F. COLYER, M.I.C.E.

DIFFERENTIAL ACCUMULATOR.



F. COLYER, M.I.C.E.

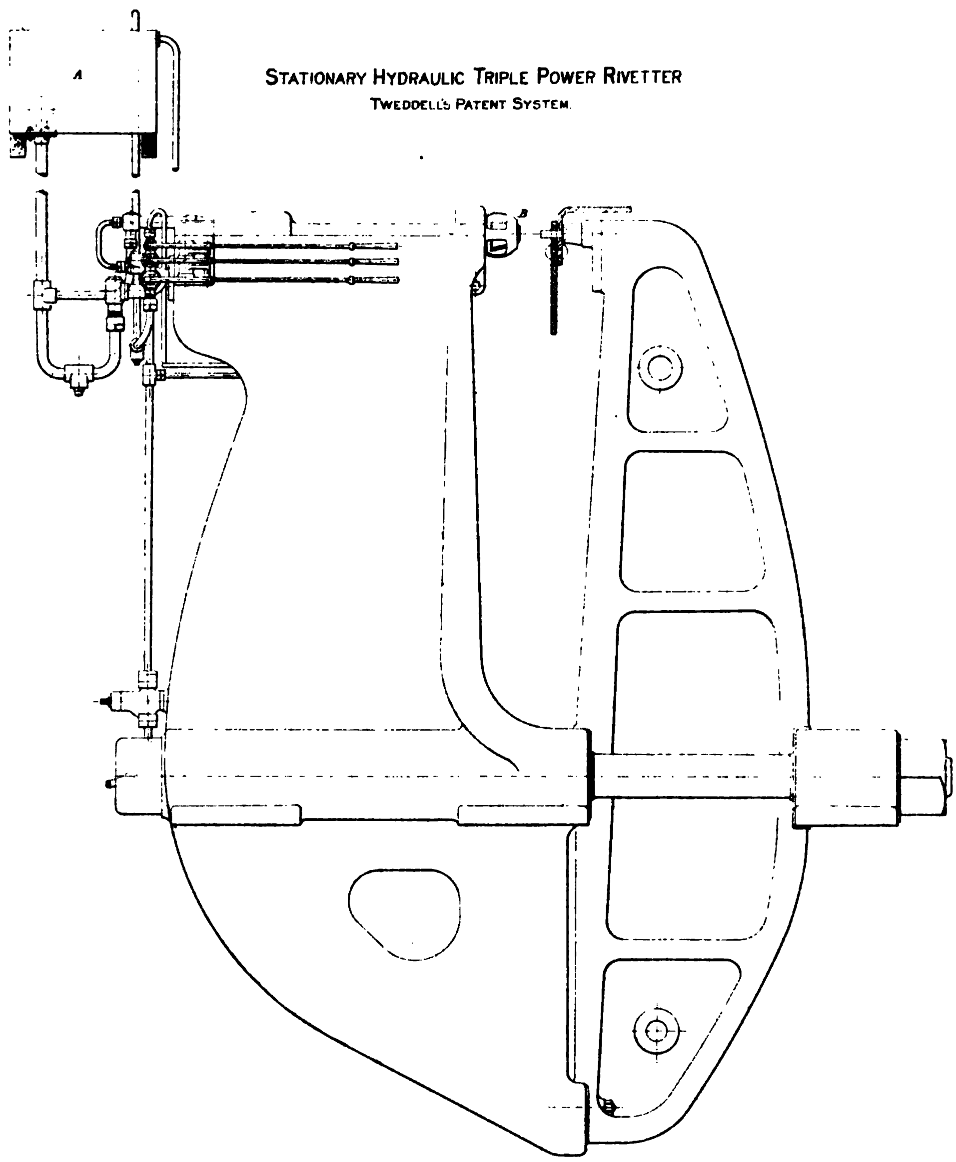
STATIONARY HYDRAULIC RIVETTING MACHINE.



F. COLYER, M.I.C.E.

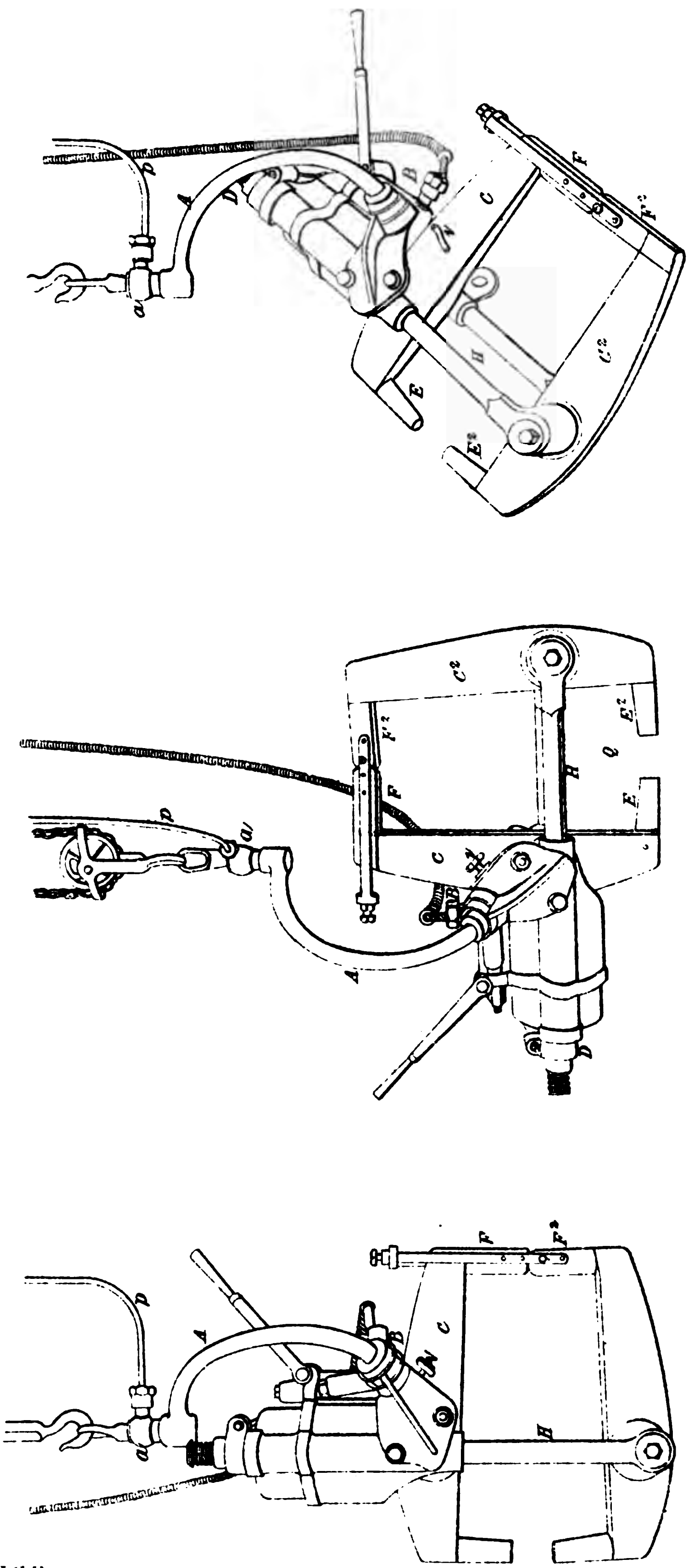
STATIONARY HYDRAULIC TRIPLE POWER RIVETTER

TWEDDELL'S PATENT SYSTEM.



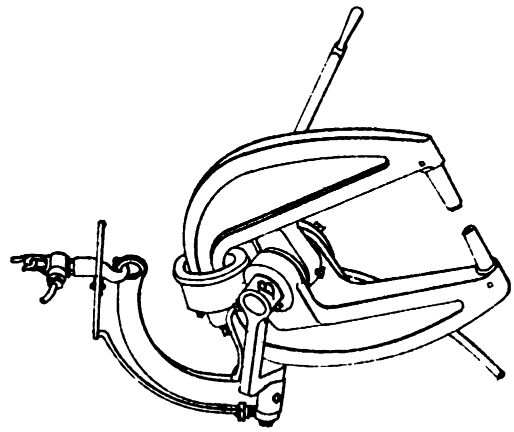
F. COLYER, M.I.C.E.

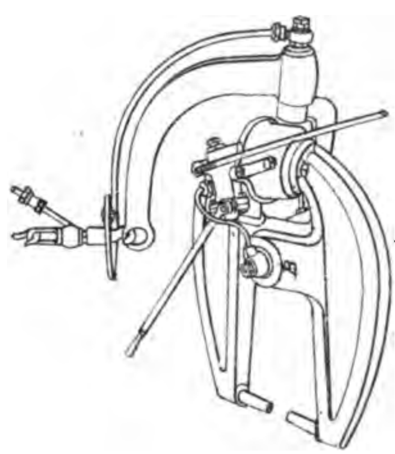
DOUBLE ENDED PORTABLE HYDRAULIC RIVETTING MACHINE.
TWEDDELLS PATENT SYSTEM.

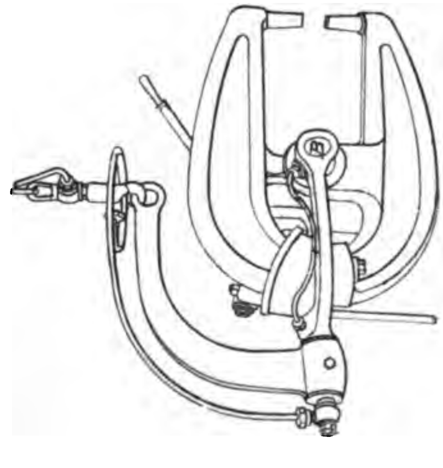


F. COLYER, M.I.C.E.

Single Ended Portable Hydraulic Rivetter
Fielding Type
Tweddell's Patent System.



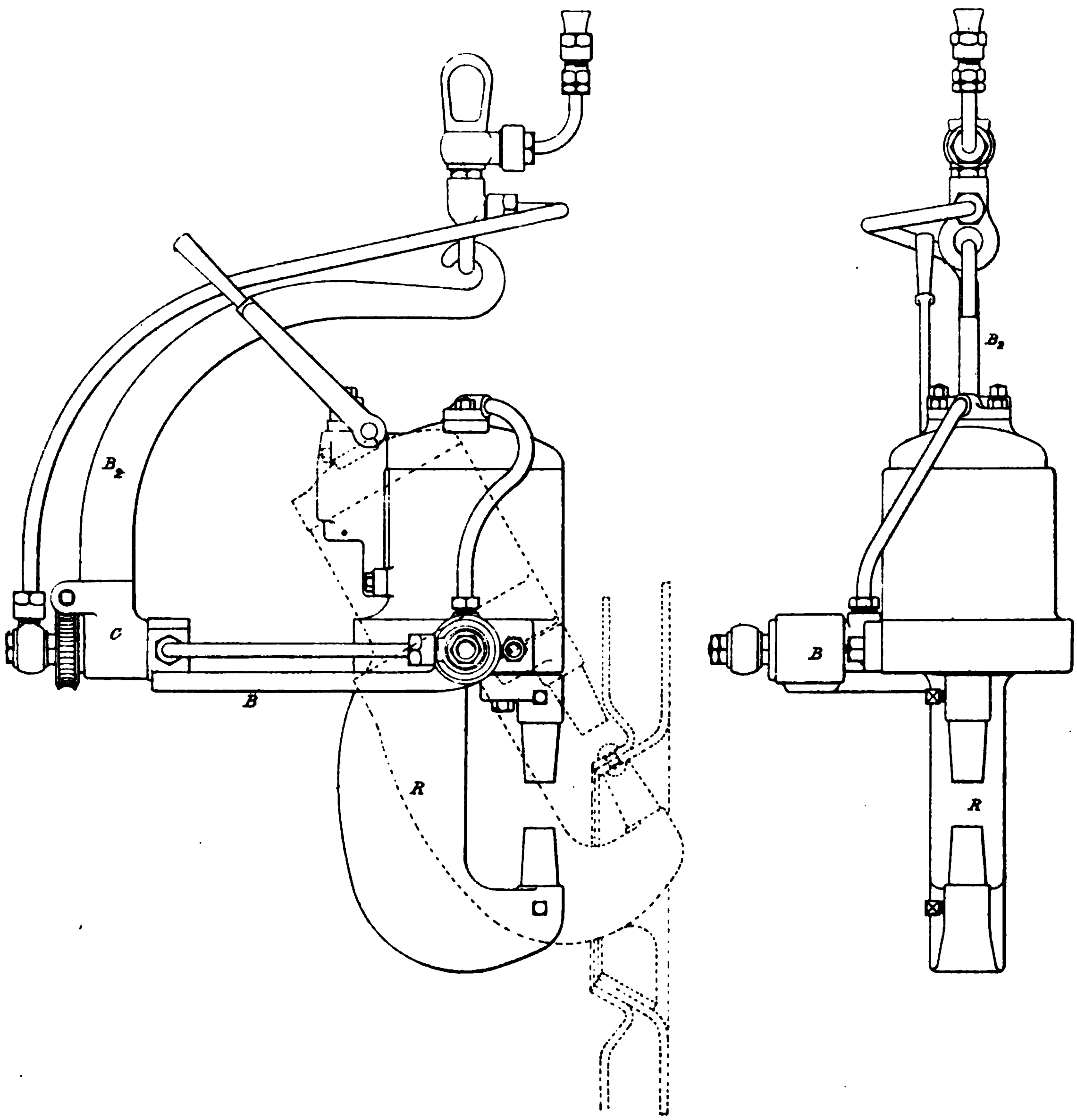




F. COLYER, M.I.C.E.

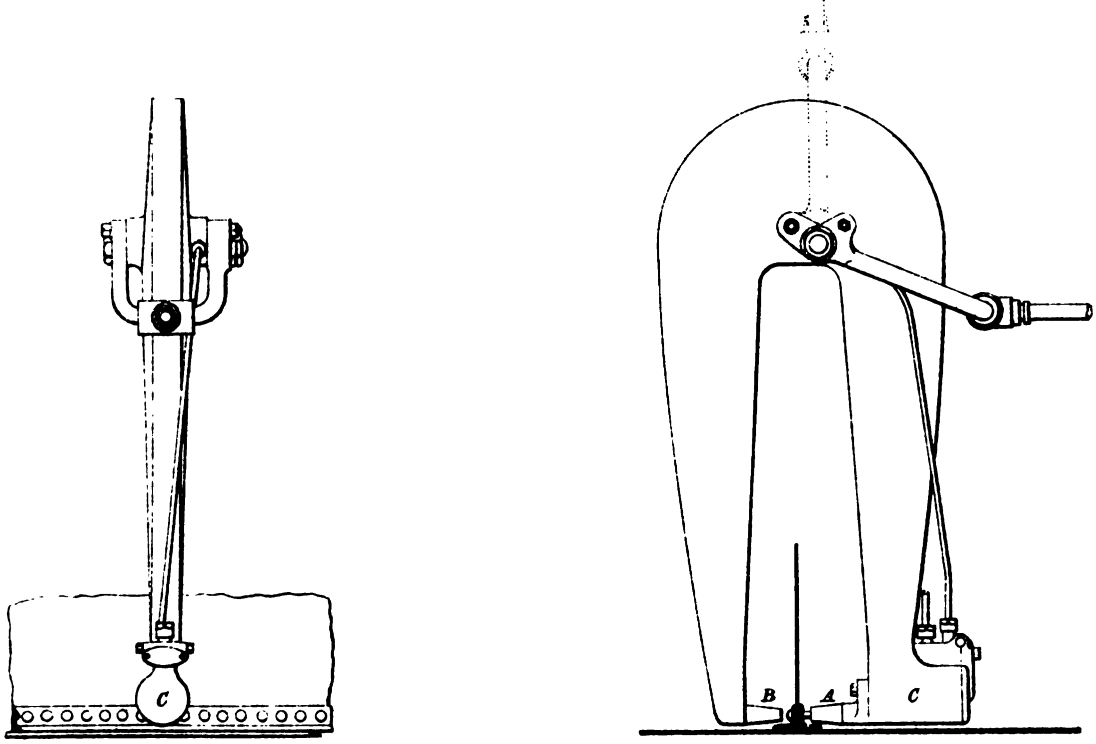
FURNACE MOUTH AND LOCOMOTIVE FOUNDATION RING RIVETTER.

TWEDDELL'S PATENT SYSTEM.

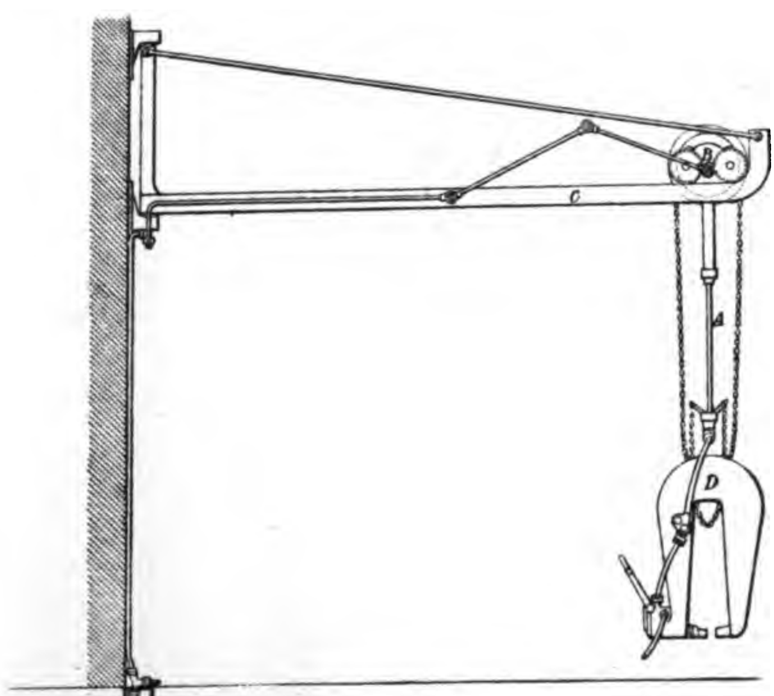


F. COLYER, M.I.C.E.

PORTABLE HYDRAULIC RIVETTING MACHINE FOR DEEP GIRDERS, TANKS, ETC.

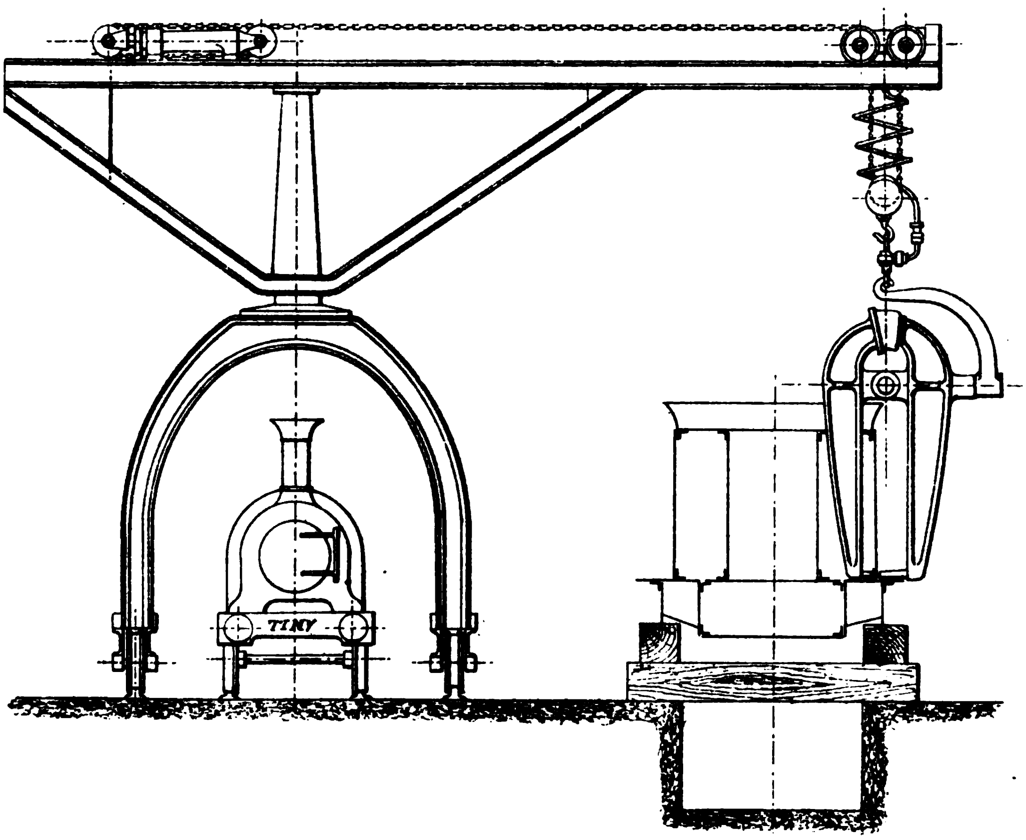


PORTABLE HYDRAULIC RIVETTER, LIFT & CRANE.



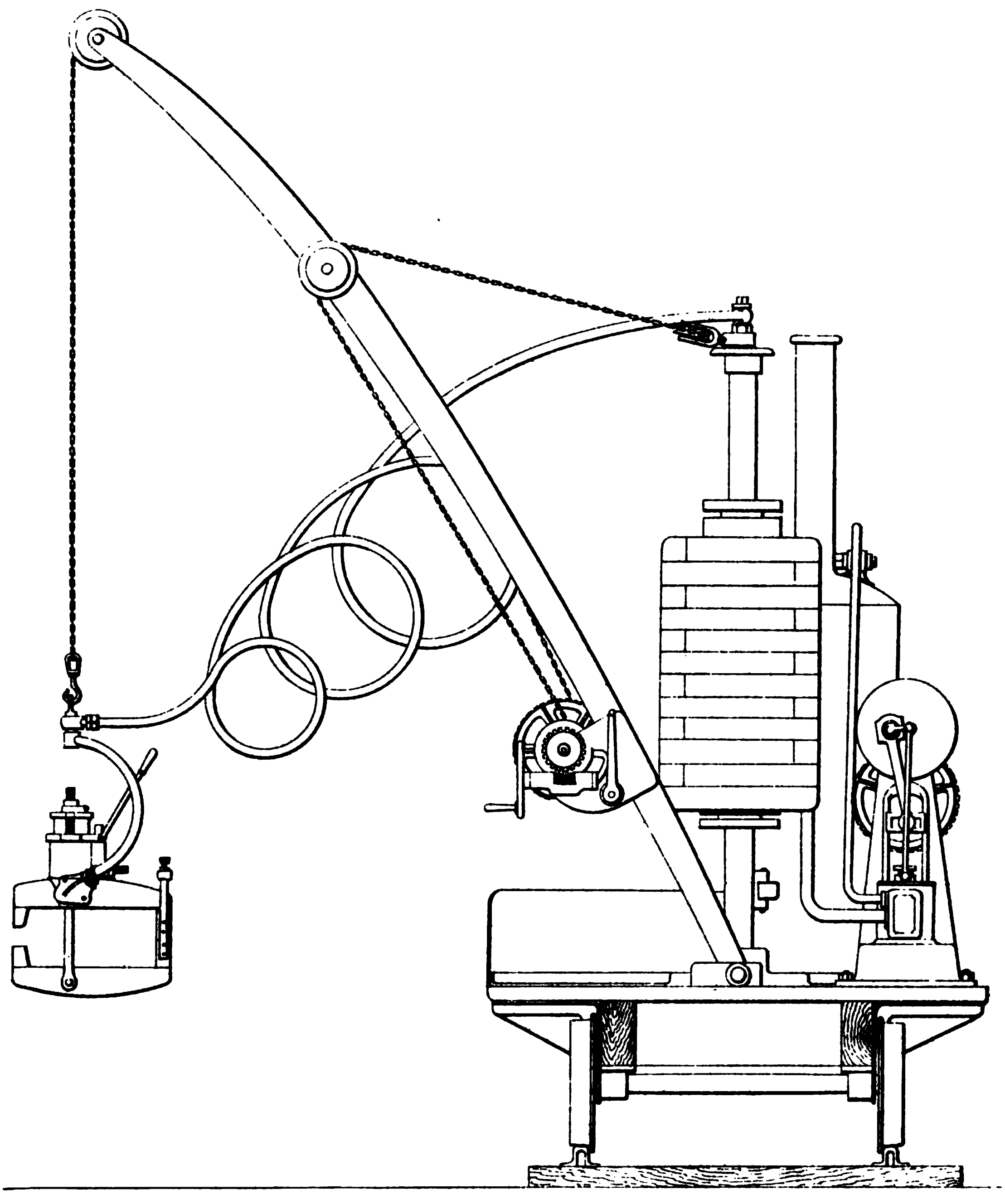
F. COLYER, M.I.C.E.

TRAVELLING HYDRAULIC CRANE & LIFT FOR LOCOMOTIVE & TENDER BUILDING SHOPS



F. COLYER, M.I.C.E.

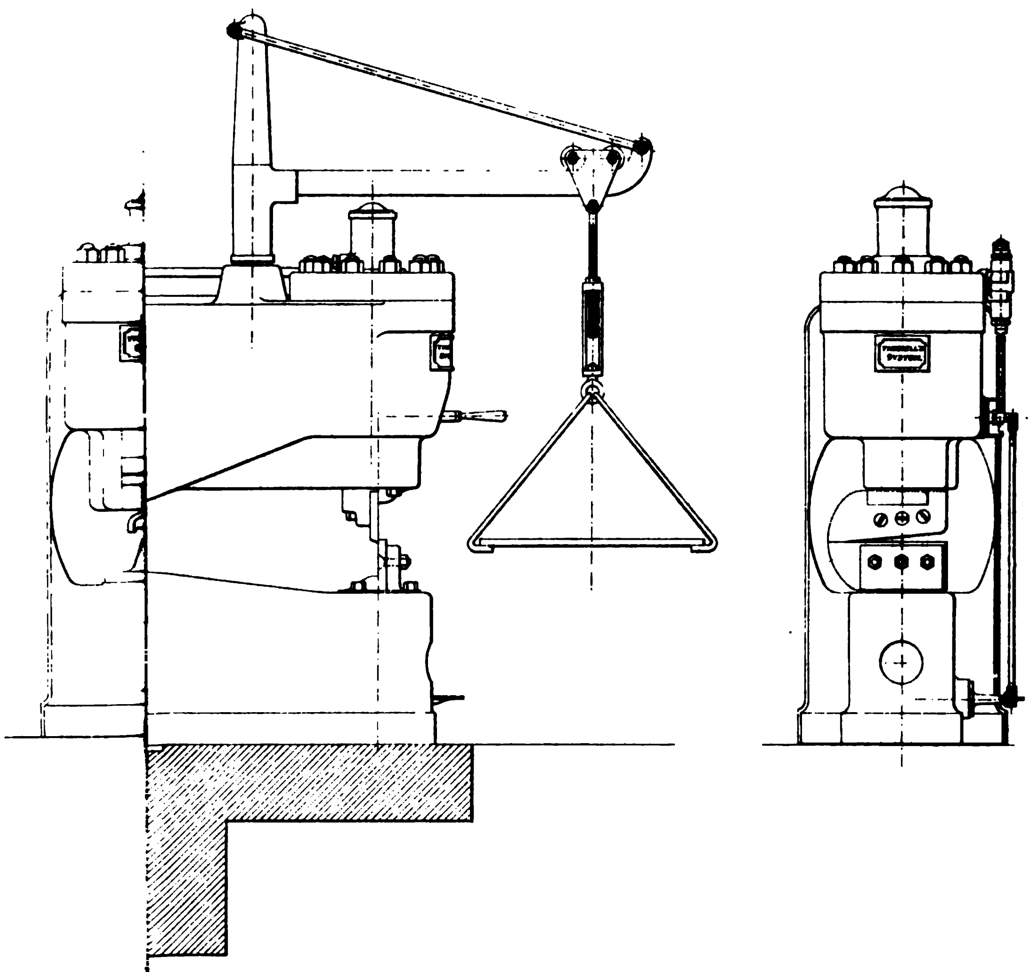
TRAVELLING PORTABLE RIVETTING PLANT.



F. COLYER, M.I.C.E.

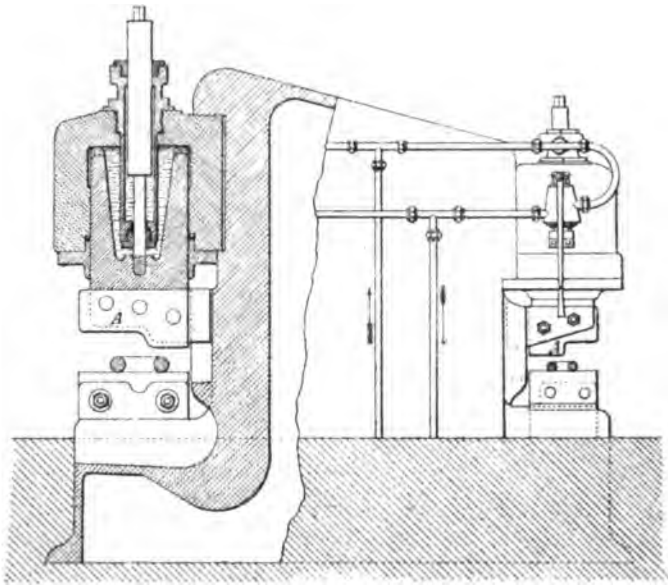
HY

DRAWING No. 54.

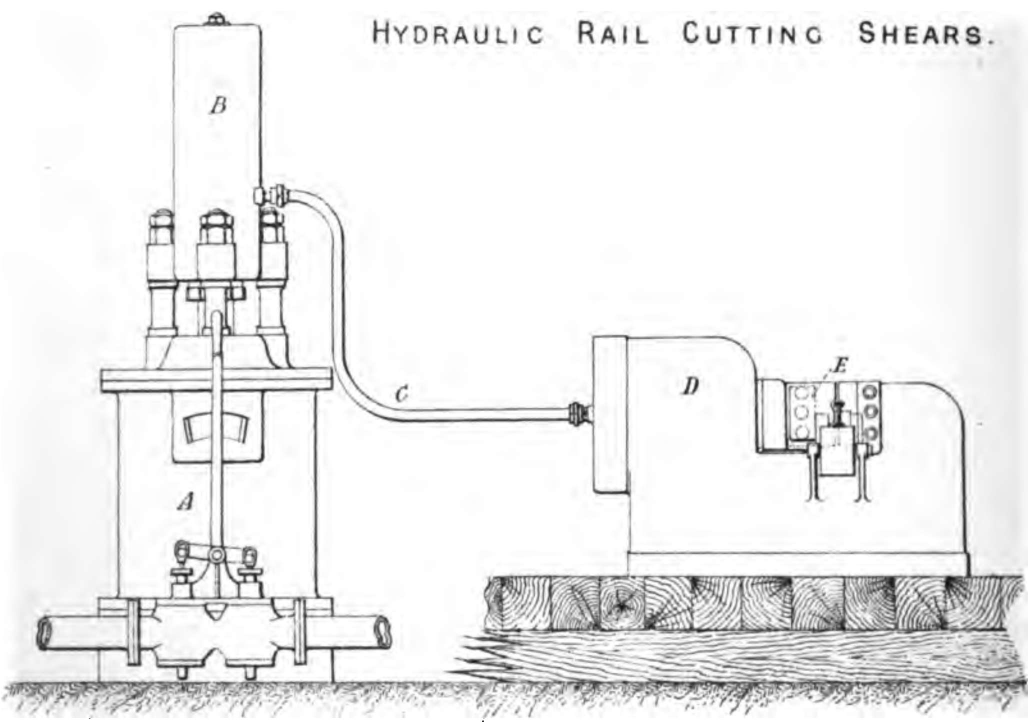


F. C

HYDRAULIC CHAIN CABLE SHEARS.

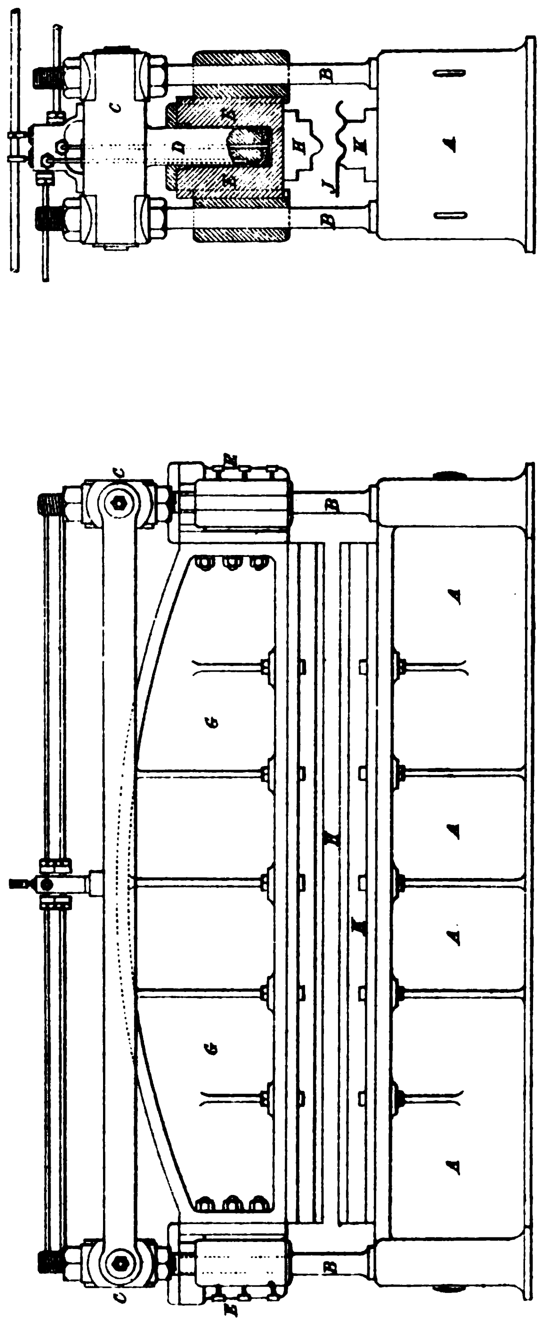


HYDRAULIC RAIL CUTTING SHEARS.



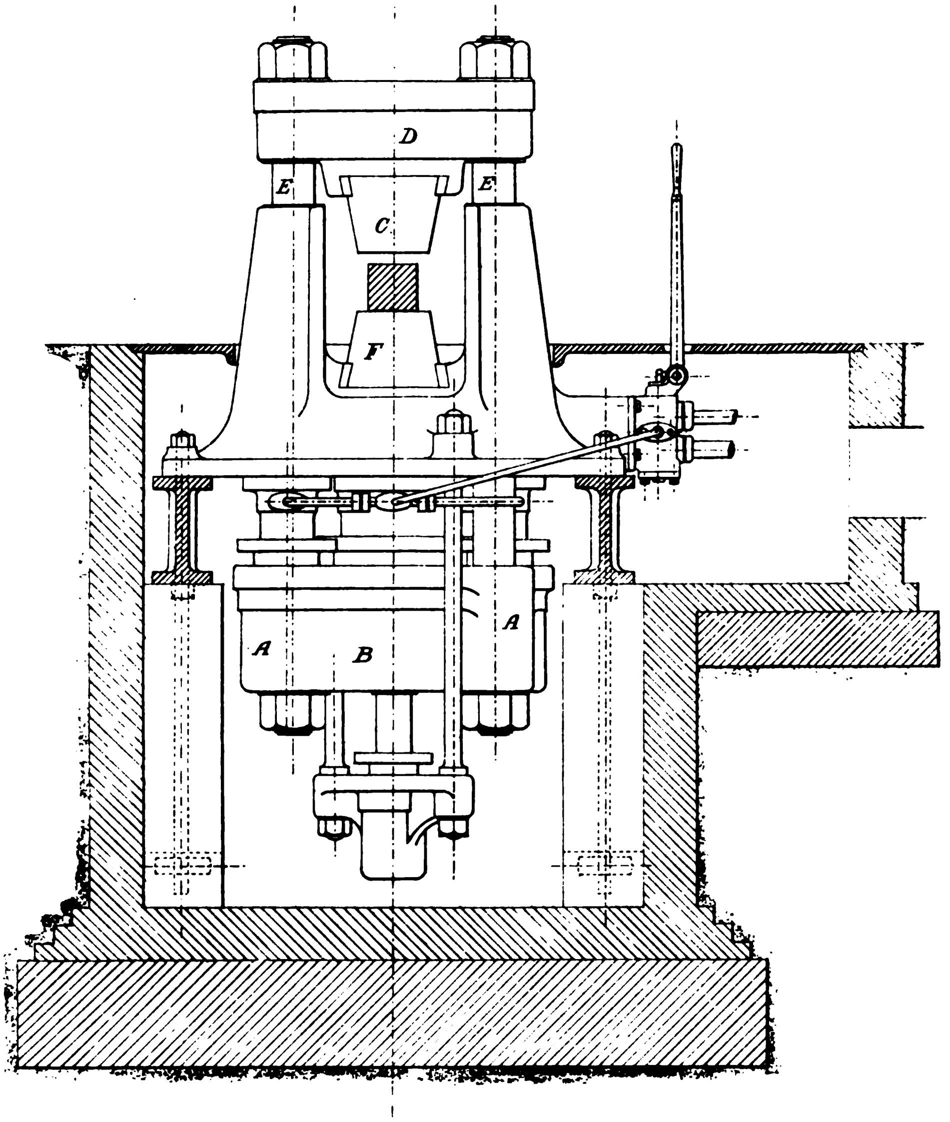
F. COLYER, M.I.C.E.

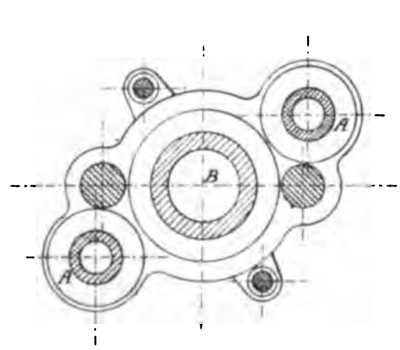
HYDRAULIC CORRUGATING PRESS.



F. COLYER. M.I.C.E.

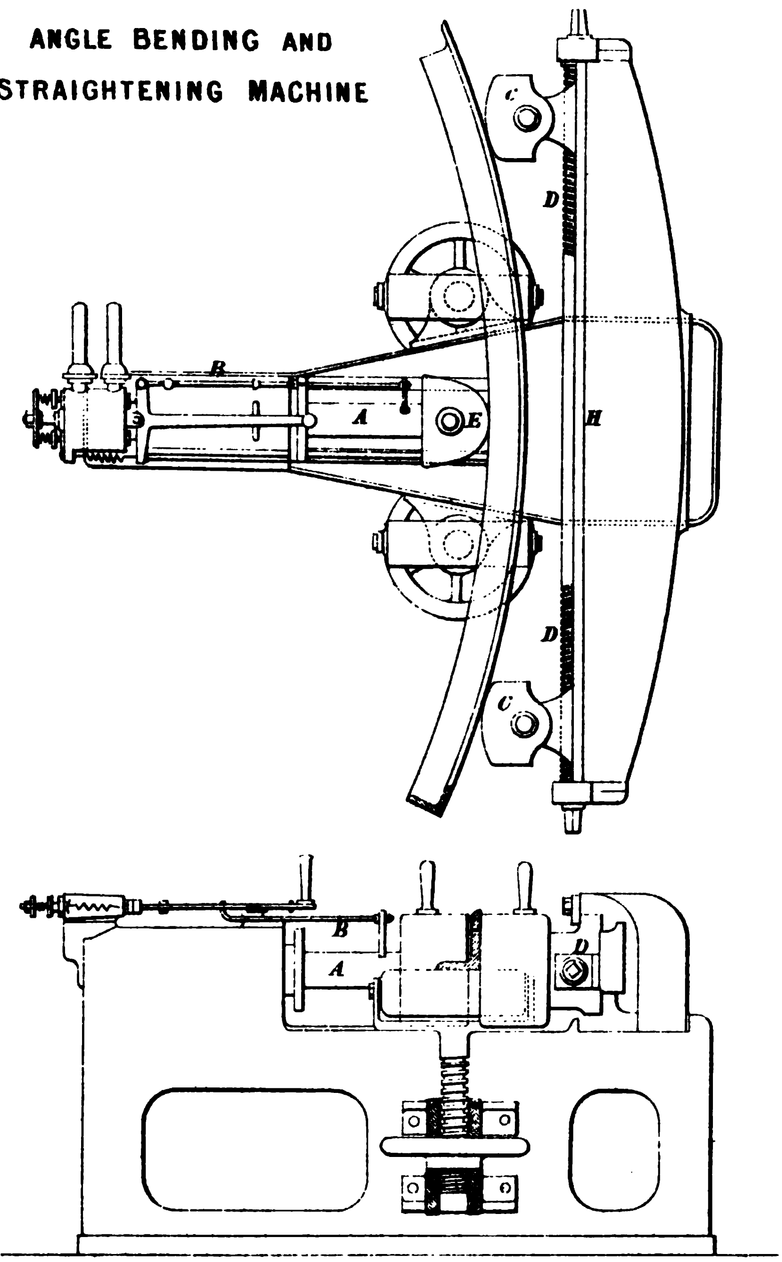
TRIPLE POWER HYDRAULIC FORCING PRESS
1500 TONS POWER





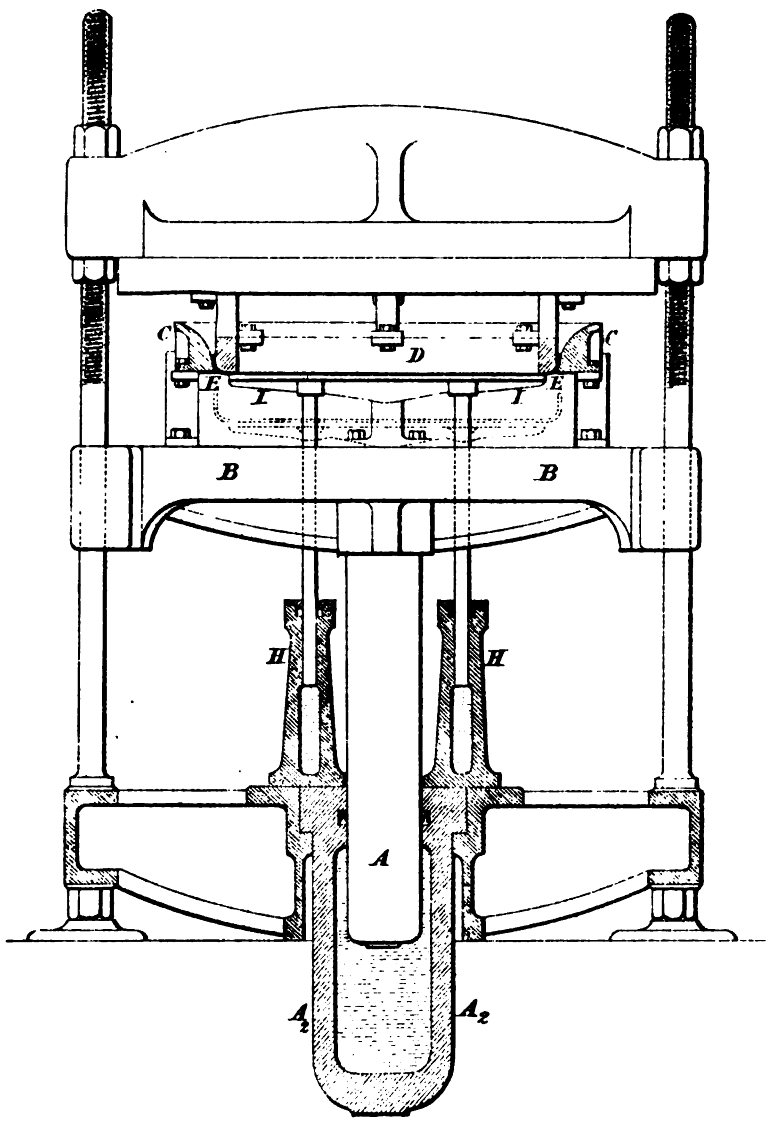
F. COLYER, M.I.C.E.

HYDRAULIC ANGLE BENDING AND STRAIGHTENING MACHINE



F. COLYER, M.I.C.E.

HYDRAULIC FLANGING MACHINE.



F. COLYER, M.I.C.E.

DRAWING No. 62.

HYDRAULIC PROGRESSIVE FLANGER & CRANE.
TWEDDELL'S PATENT SYSTEM.

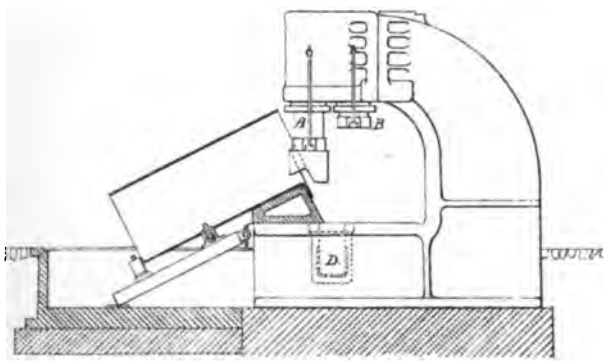


FIG. 4

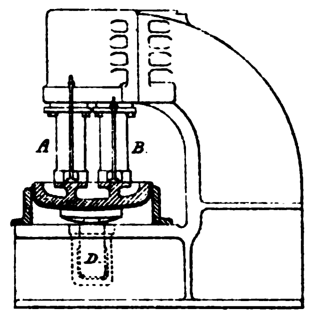


FIG. 3

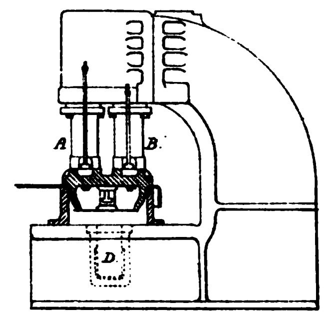


FIG. 2

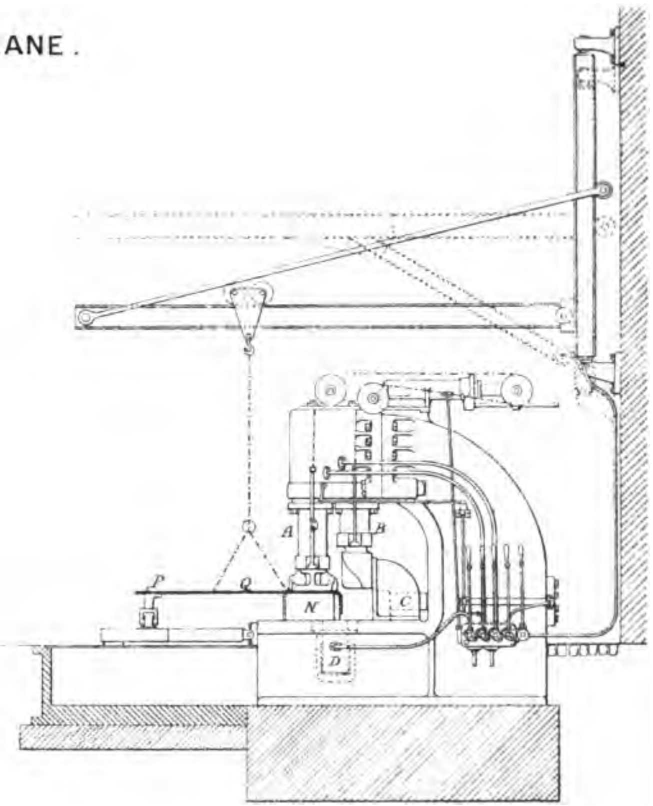
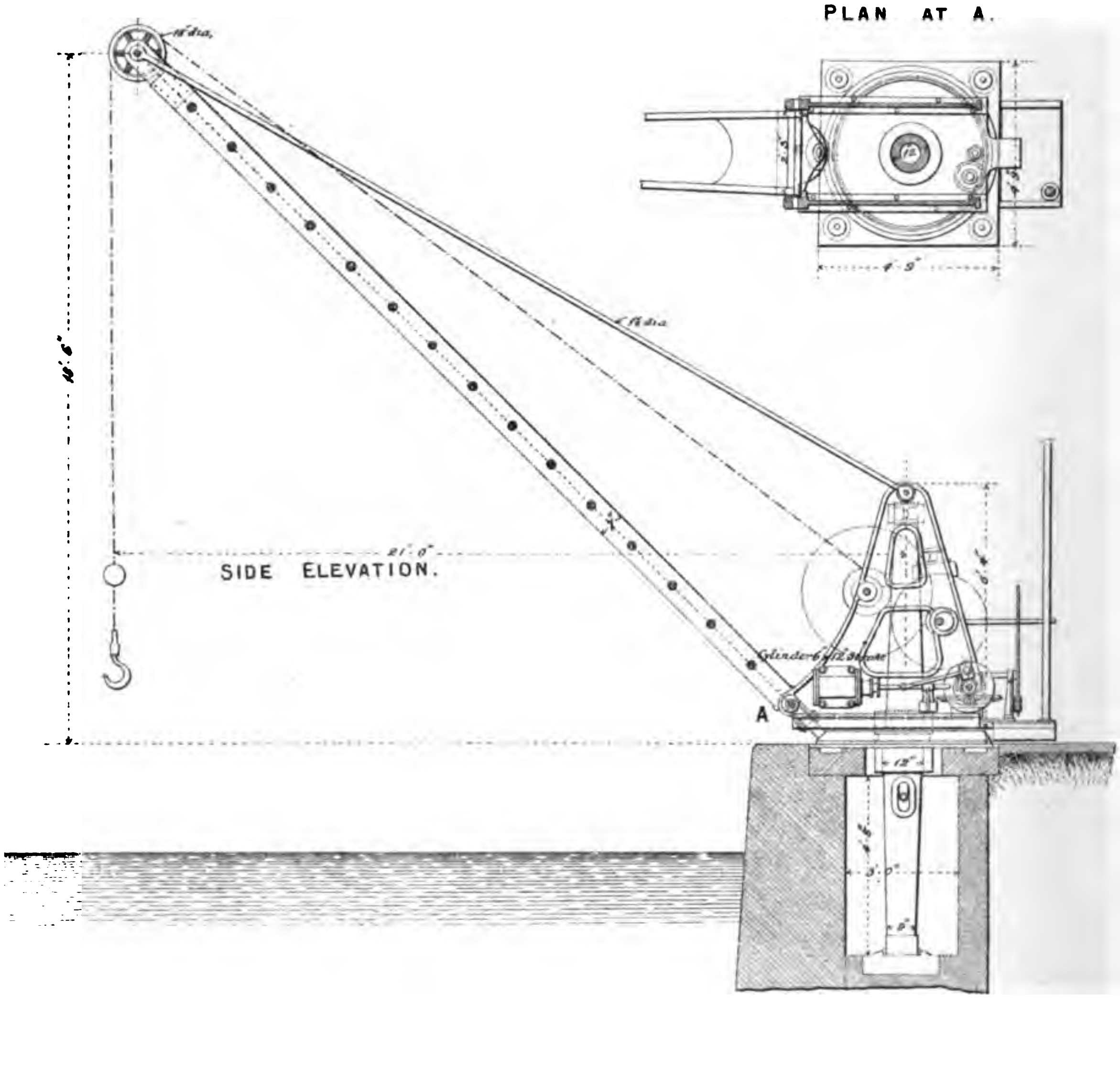


FIG. 1

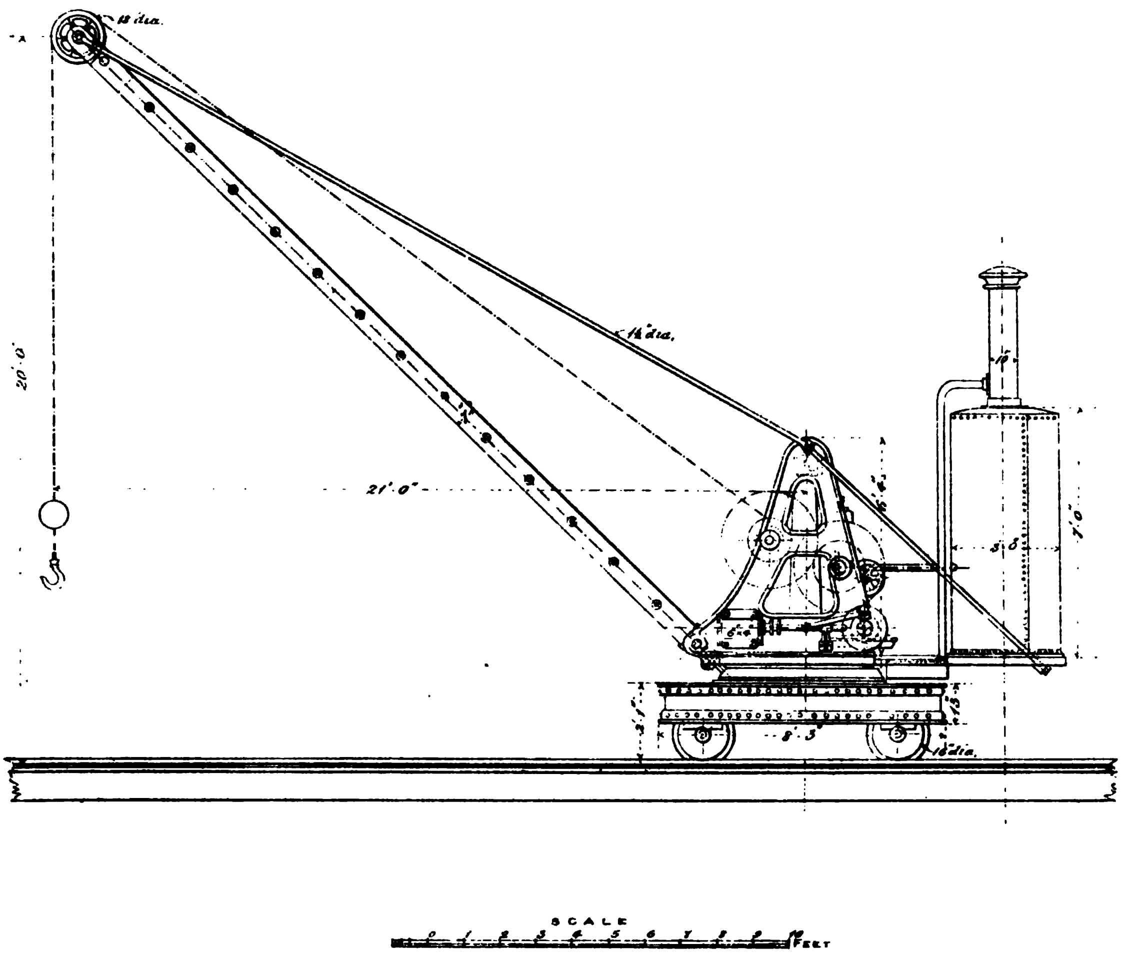
F. COLYER, M.I.C.E.

STEAM WHARF CRANE.



F. COLYER, M.I.C.E.

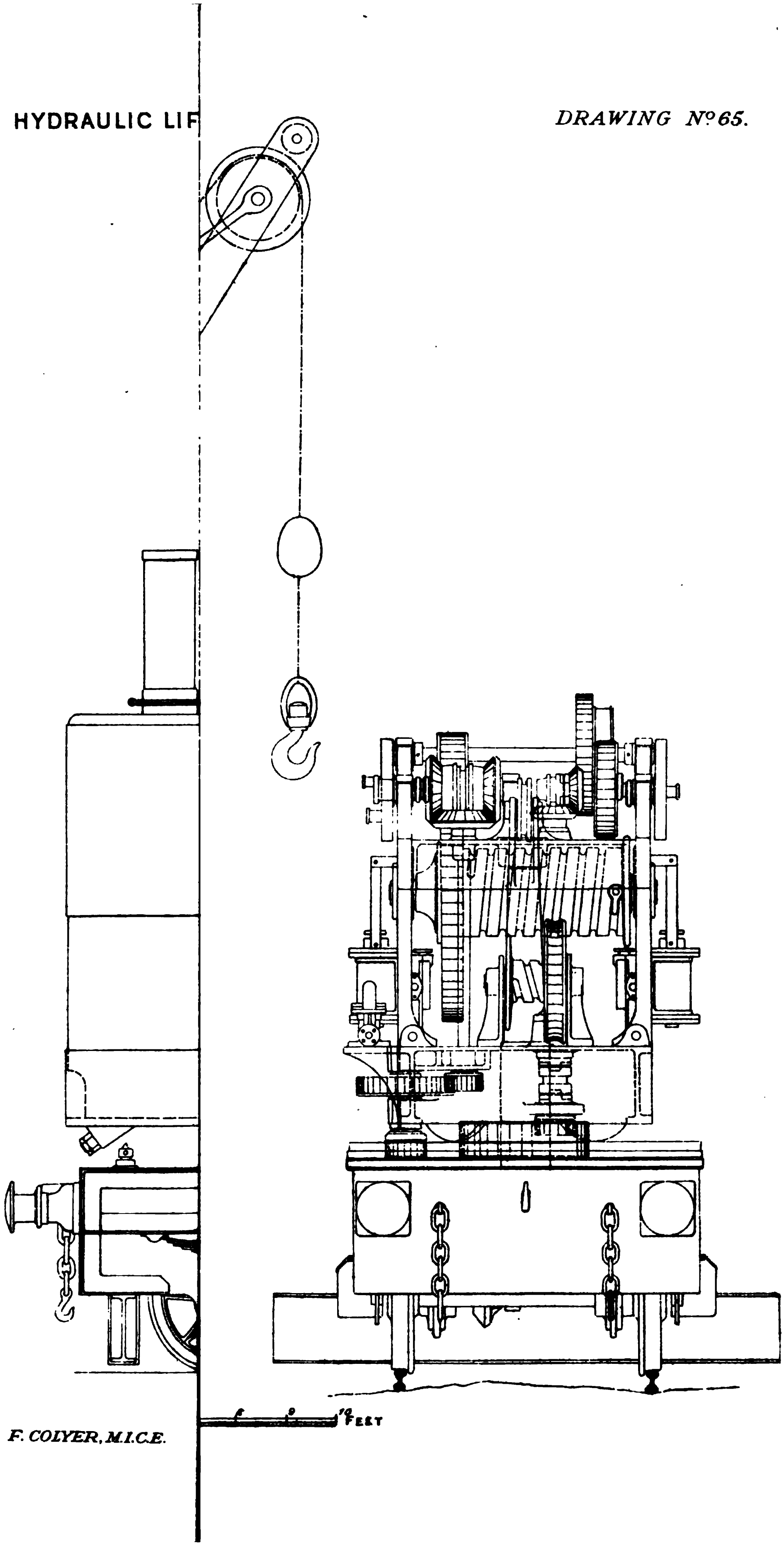
PORTABLE STEAM WHARF CRANE.



F. COLYER, M.I.C.E.

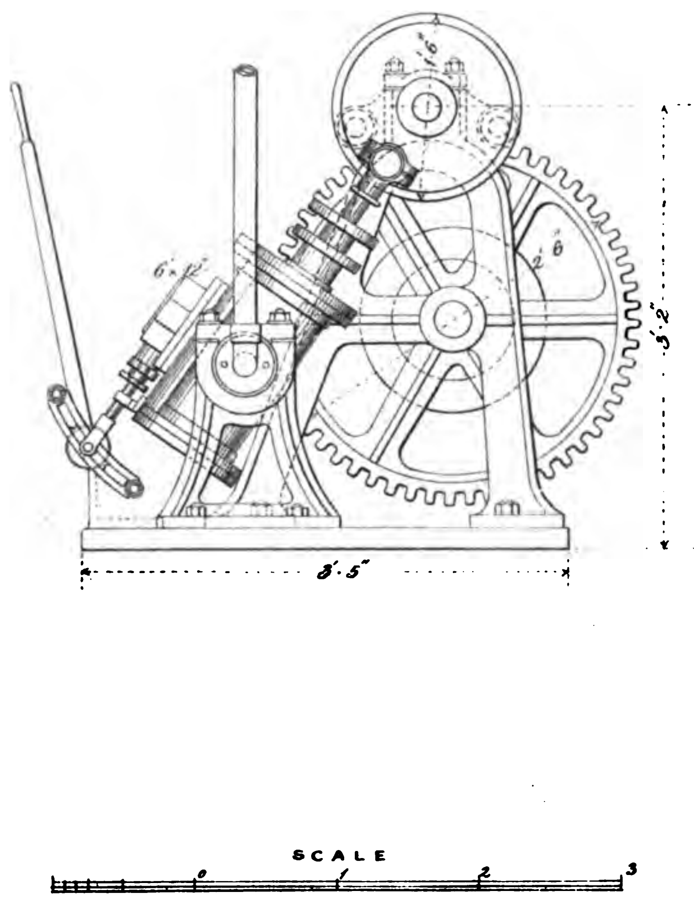
HYDRAULIC LIF

DRAWING N°65.



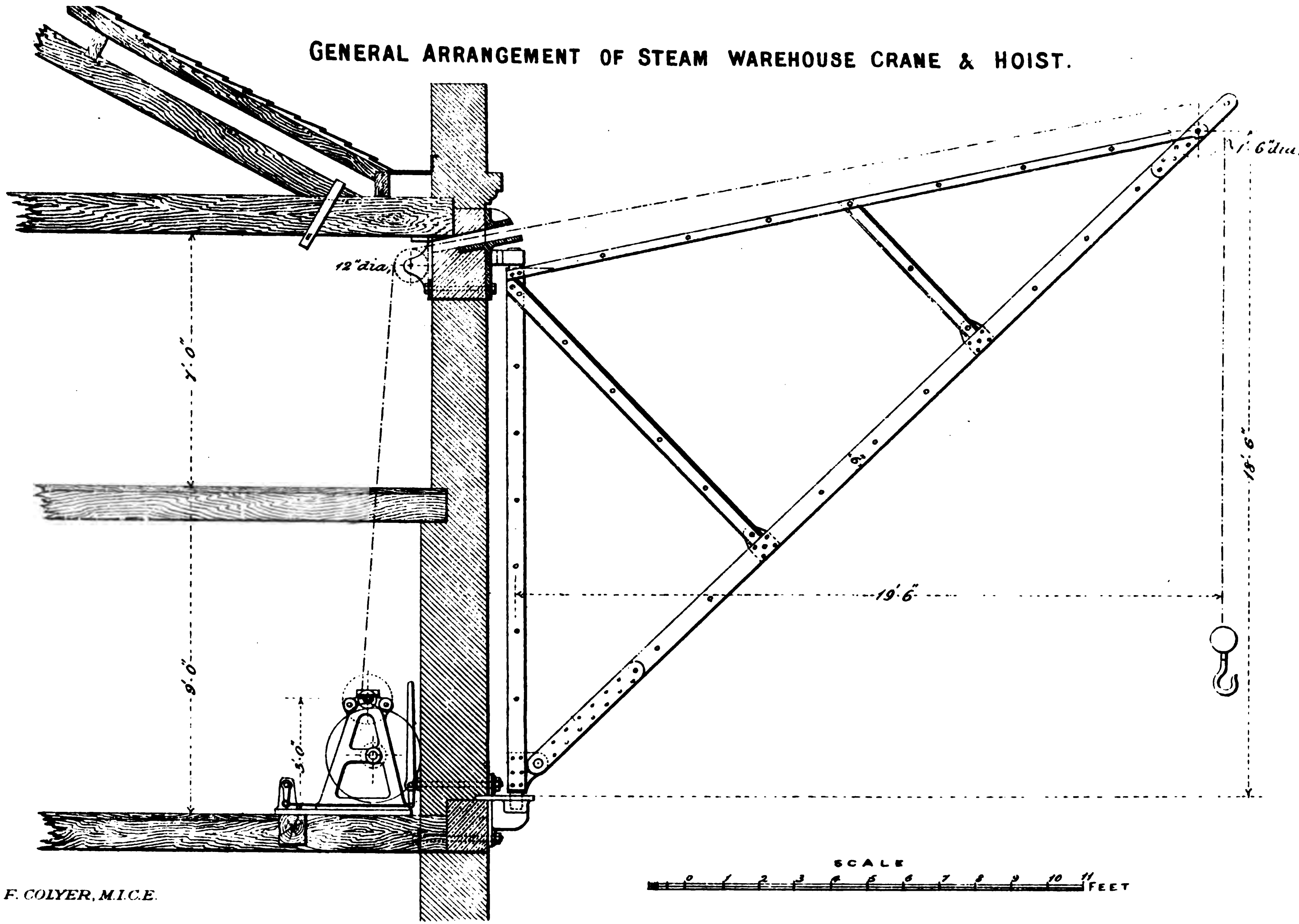
F. COLYER, M.I.C.E.

STEAM HOIST FOR 30 OR 40 CWT



F. COLYER, M.I.C.E.

GENERAL ARRANGEMENT OF STEAM WAREHOUSE CRANE & HOIST.



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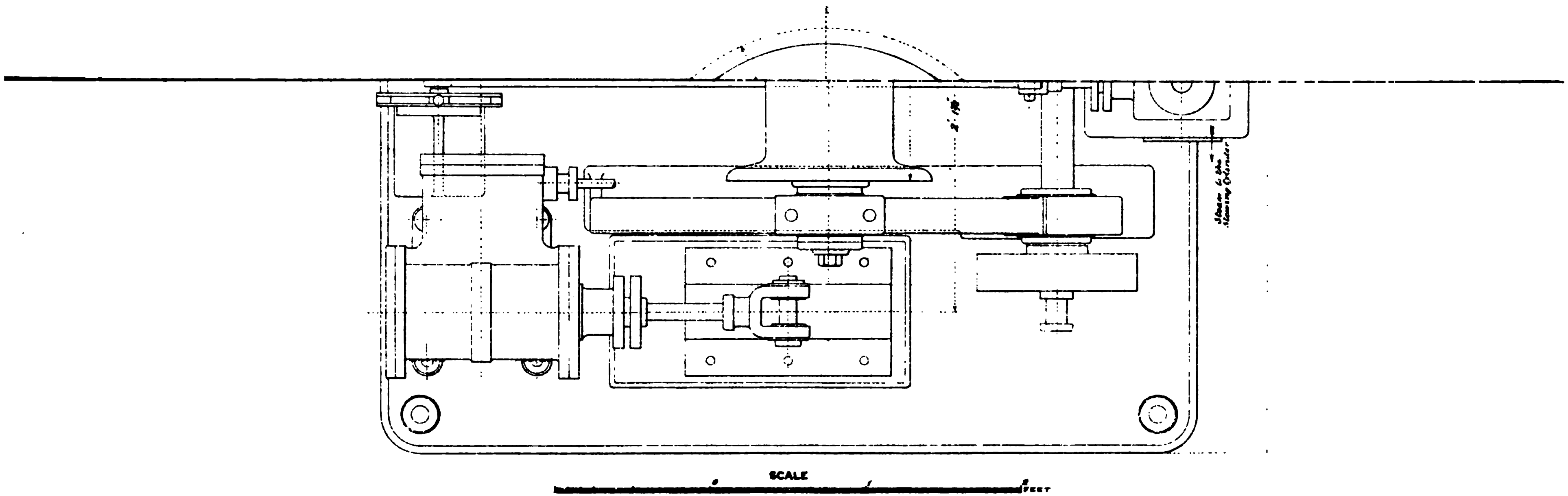
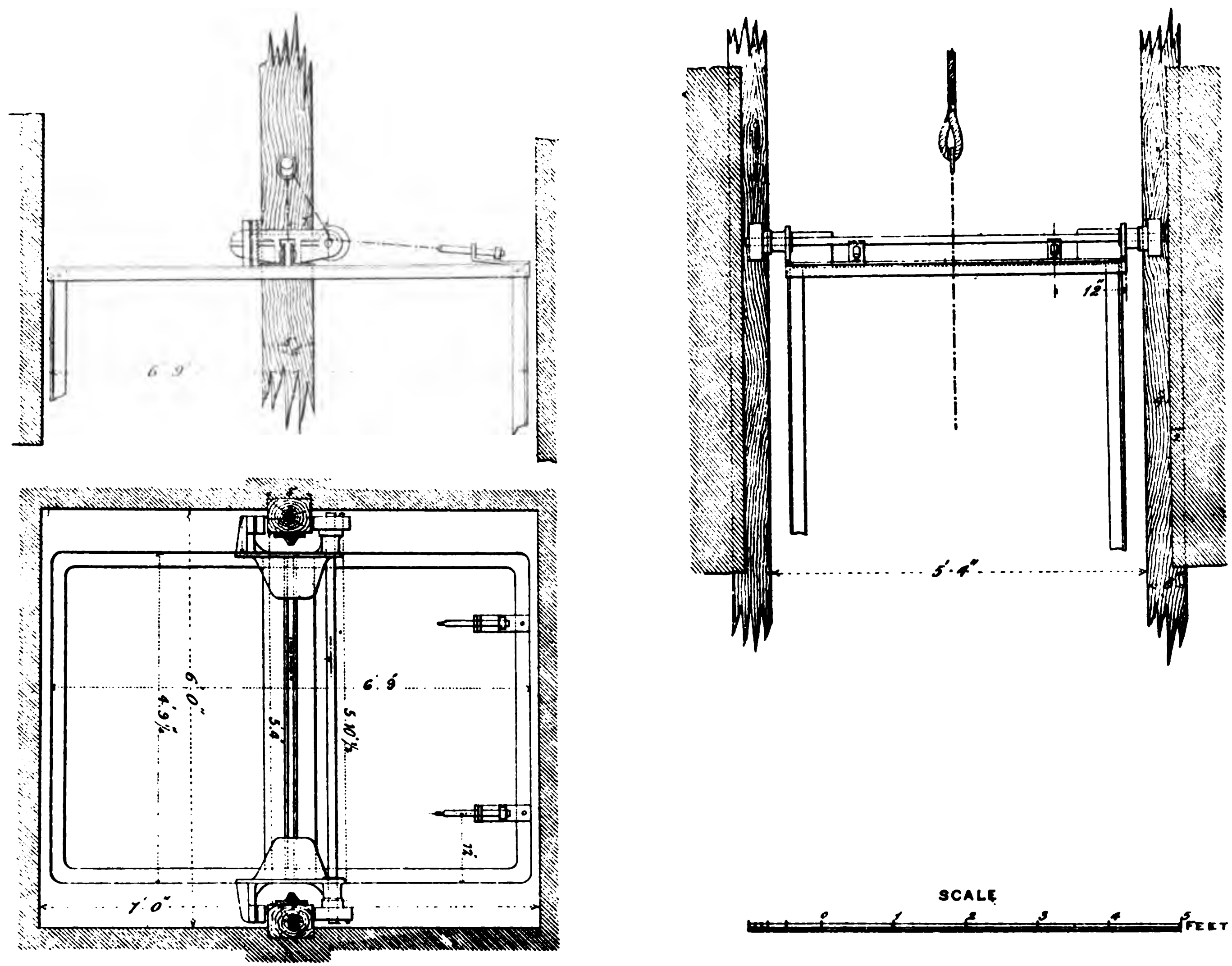
DRAWING No. 68.



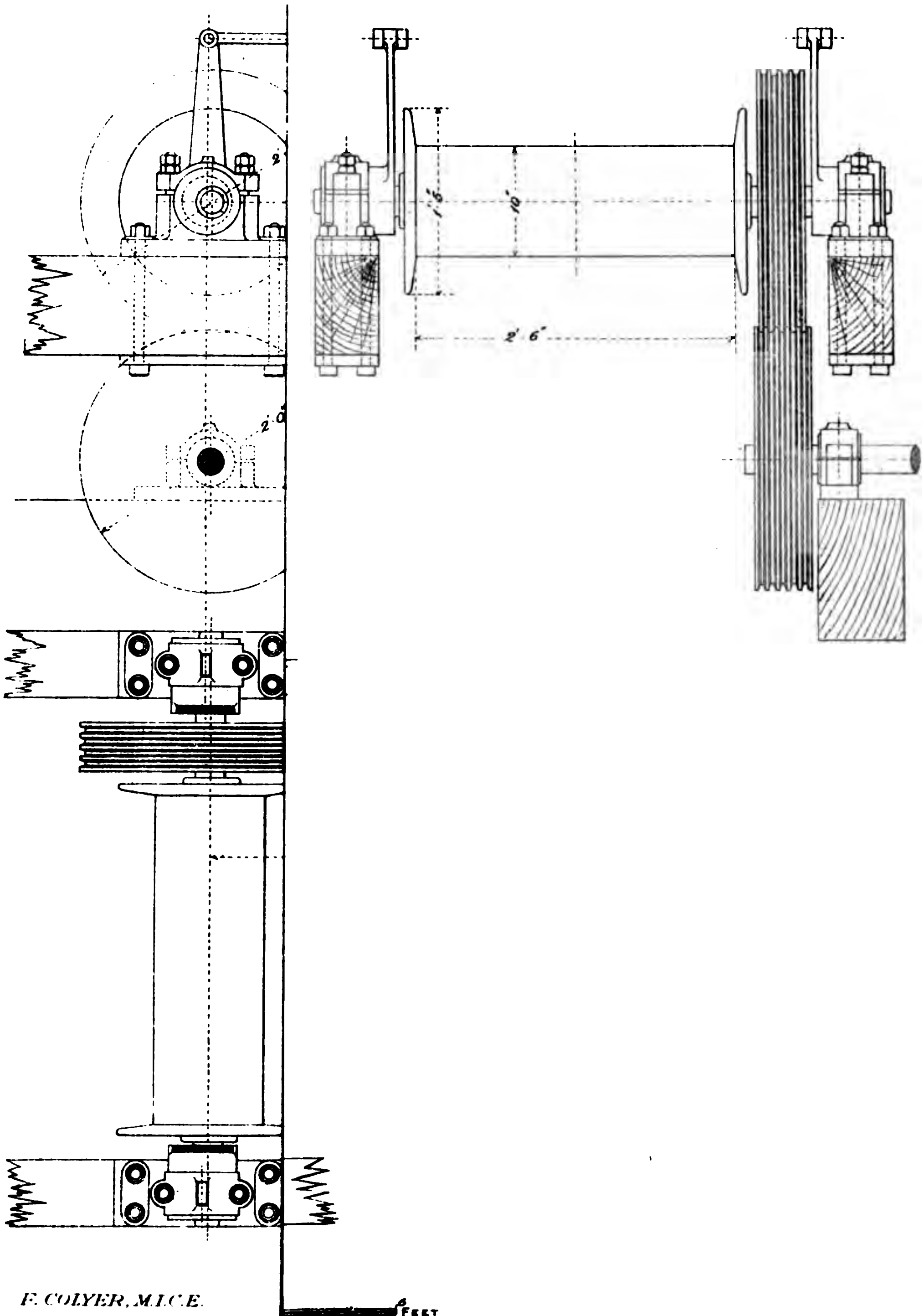
F. COLYER, M.I.C.E

SAFETY GEAR FOR CAGES OF LIFTING APPARATUS.

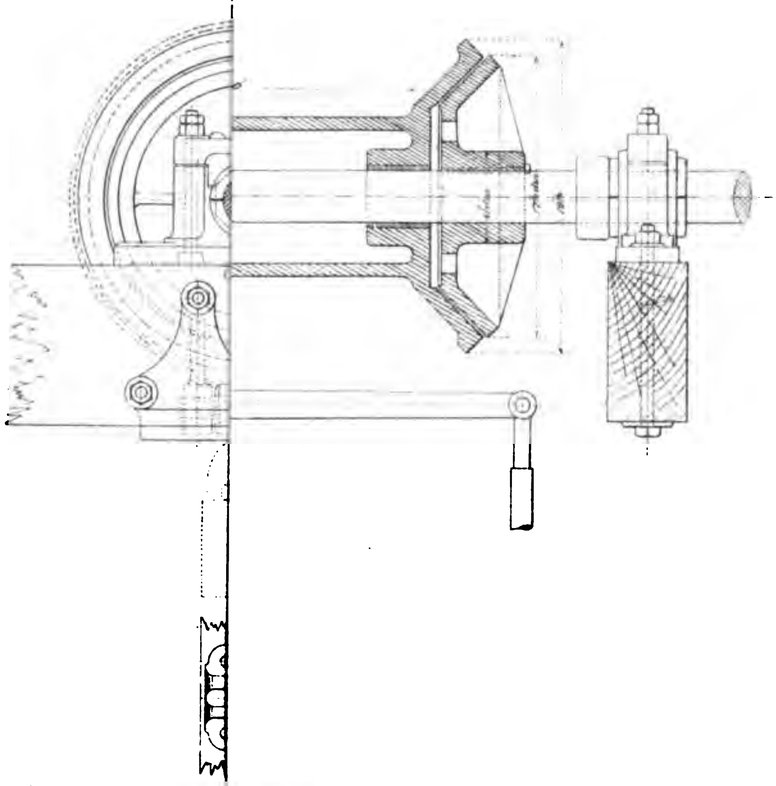


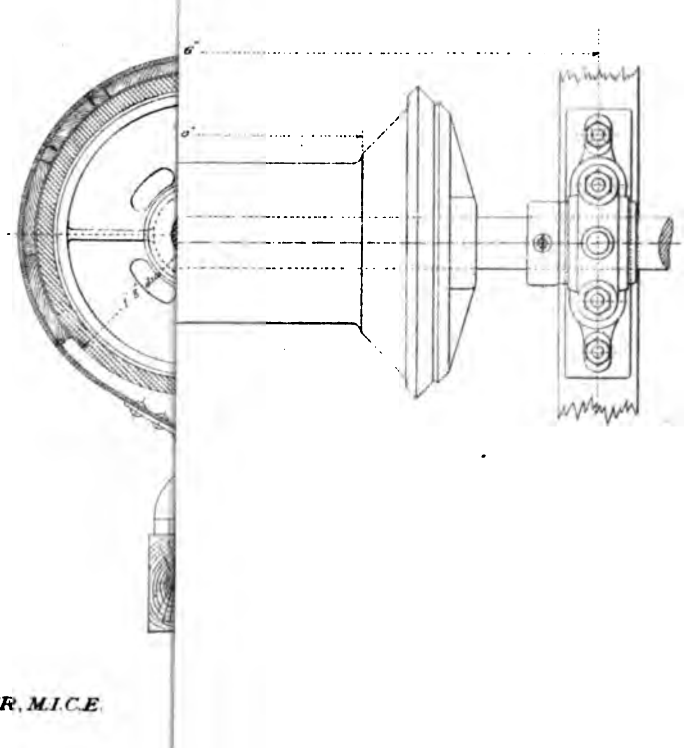
F. COLYER, M.I.C.E

DRAWING No 71.



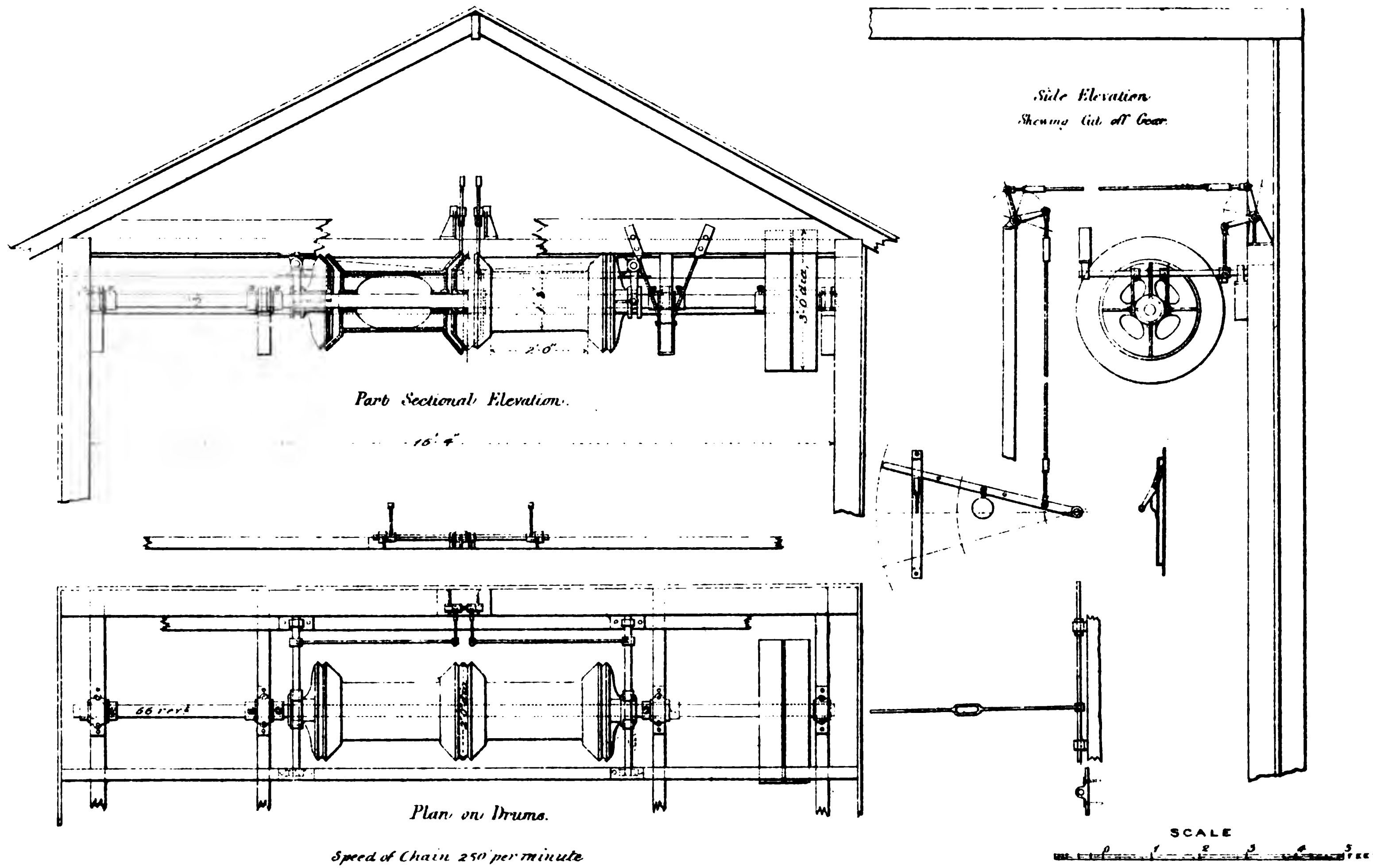
F. COLYER, M.I.C.E.





F. COLYER, M.I.C.E.

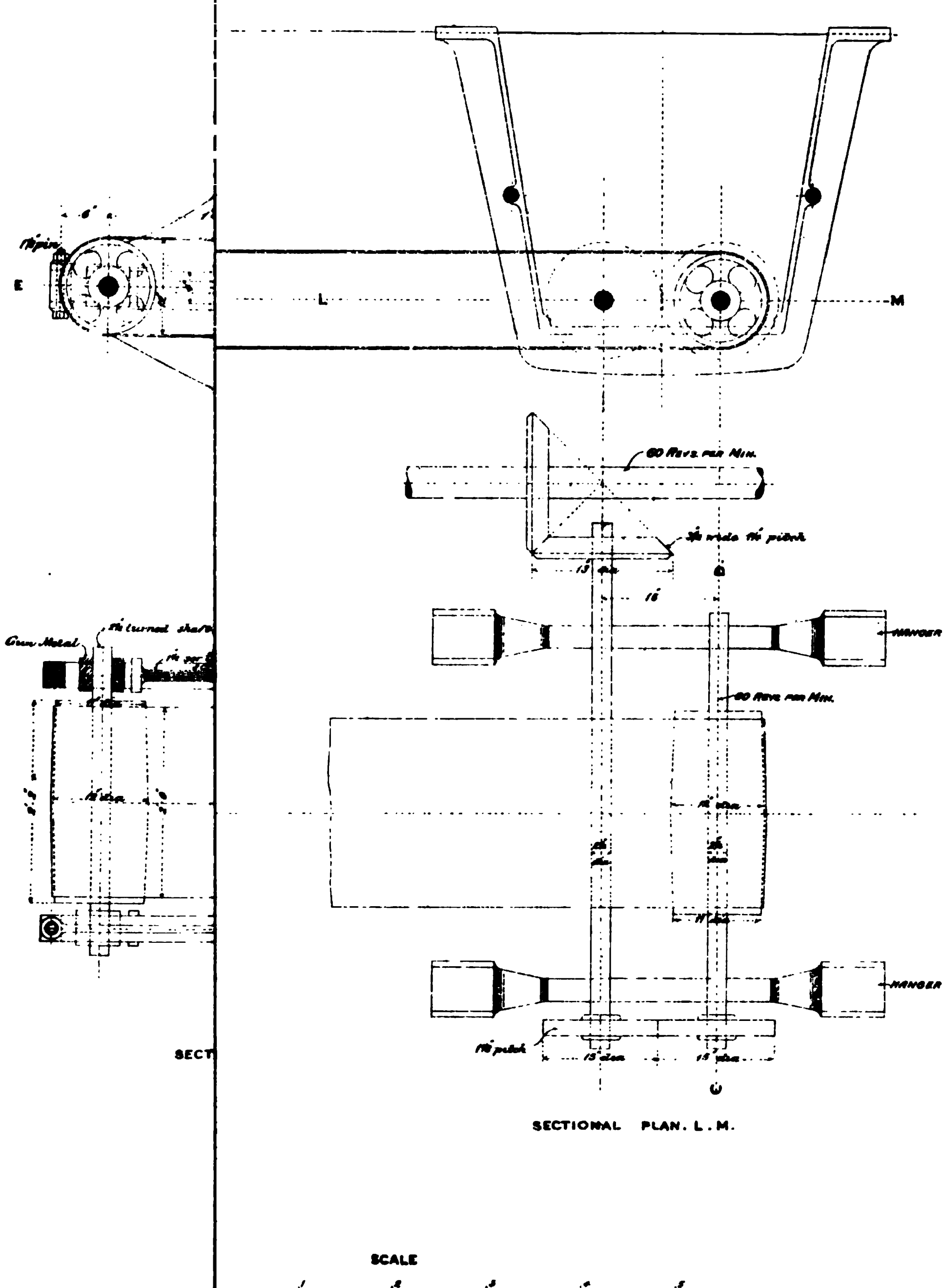
DOUBLE SACK TACKLE WORKED BY CONE GEAR.



E. COLYER, M.I.C.E.

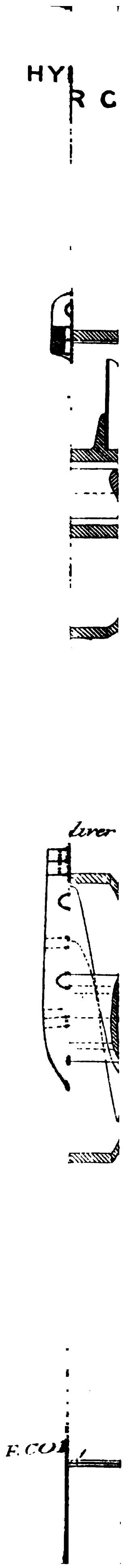
HYDRAULIC L

DRAWING No. 74.

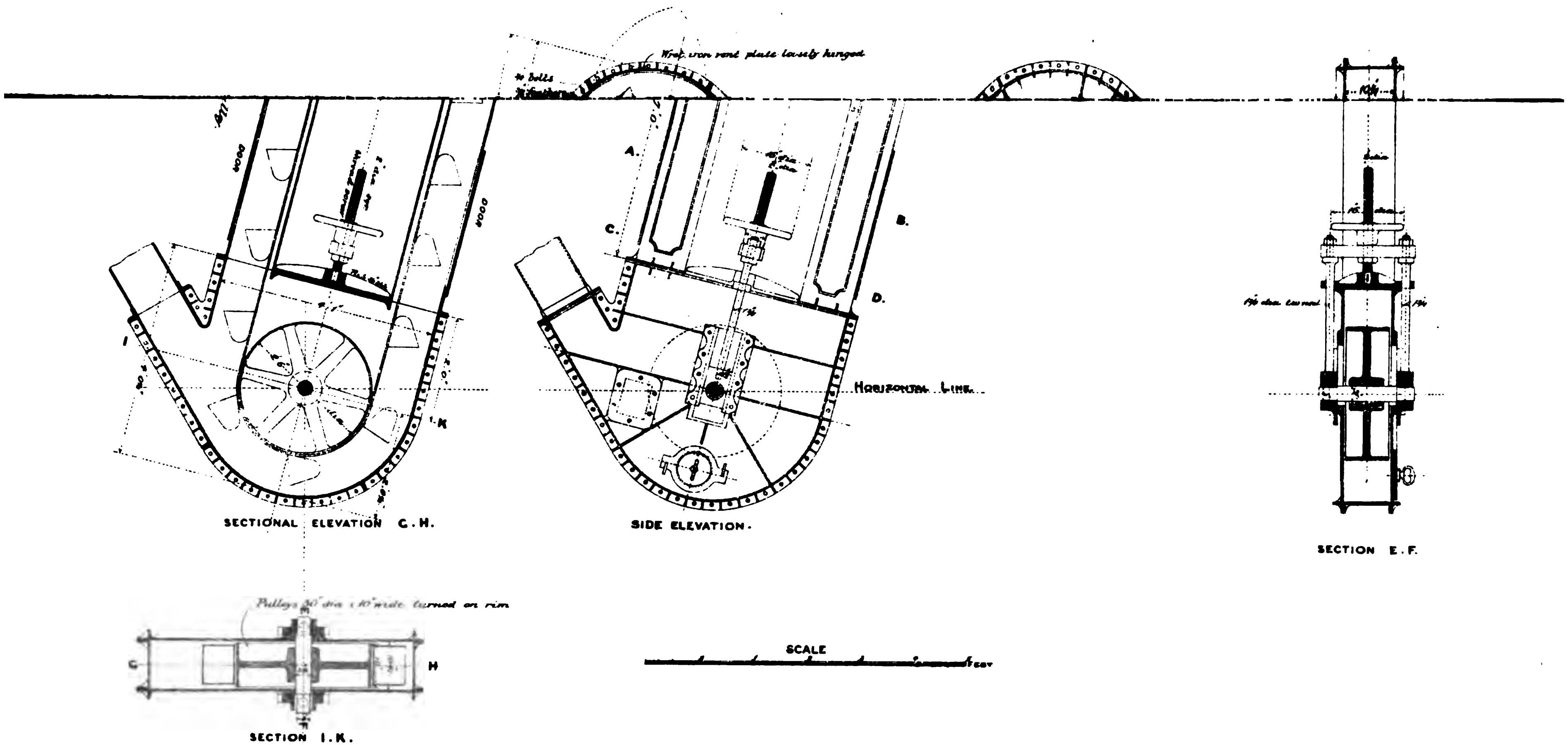


SECTIONAL PLAN. L. M.

F. COLYER, M.I.C.

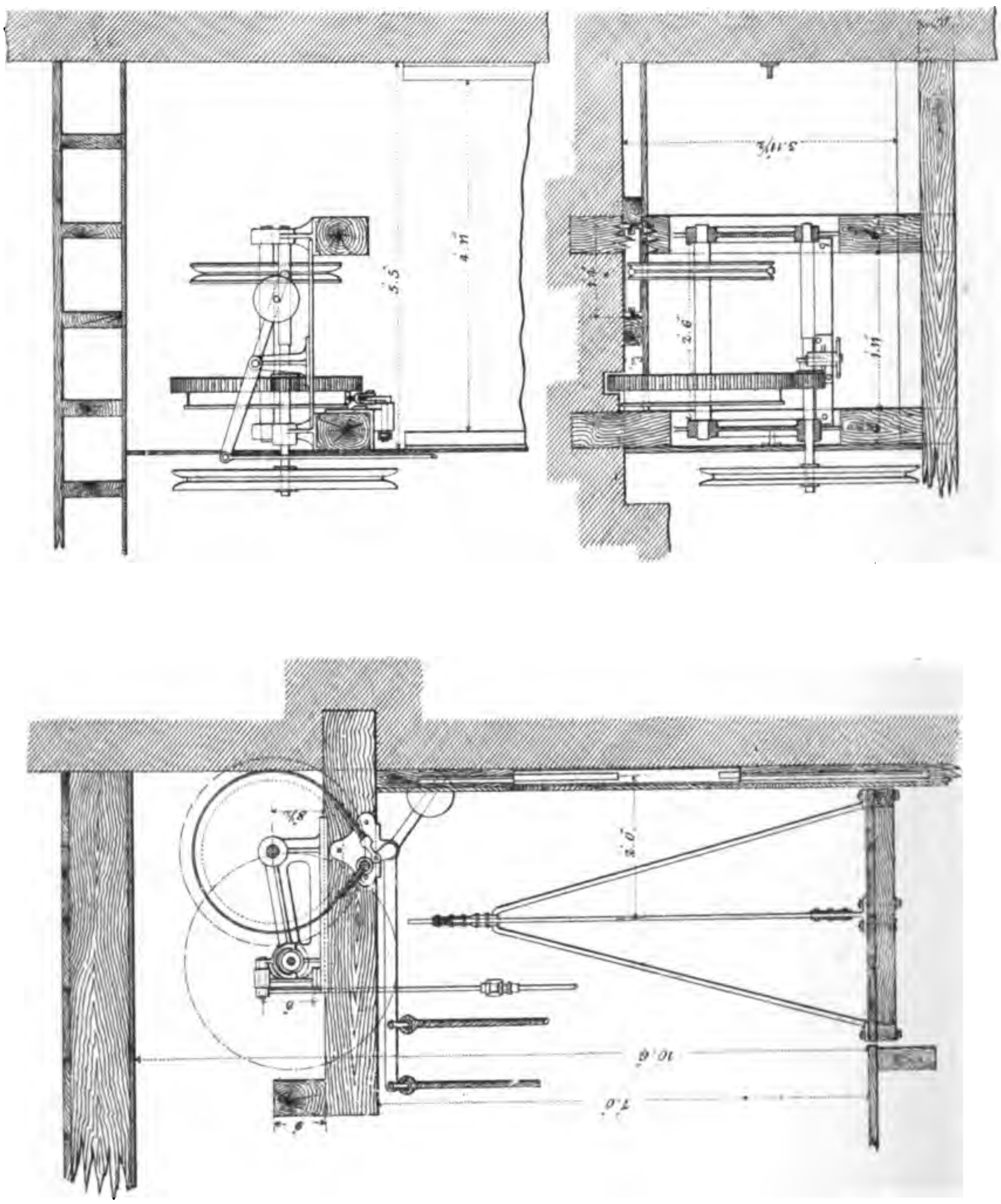


GRAIN ELEVATOR



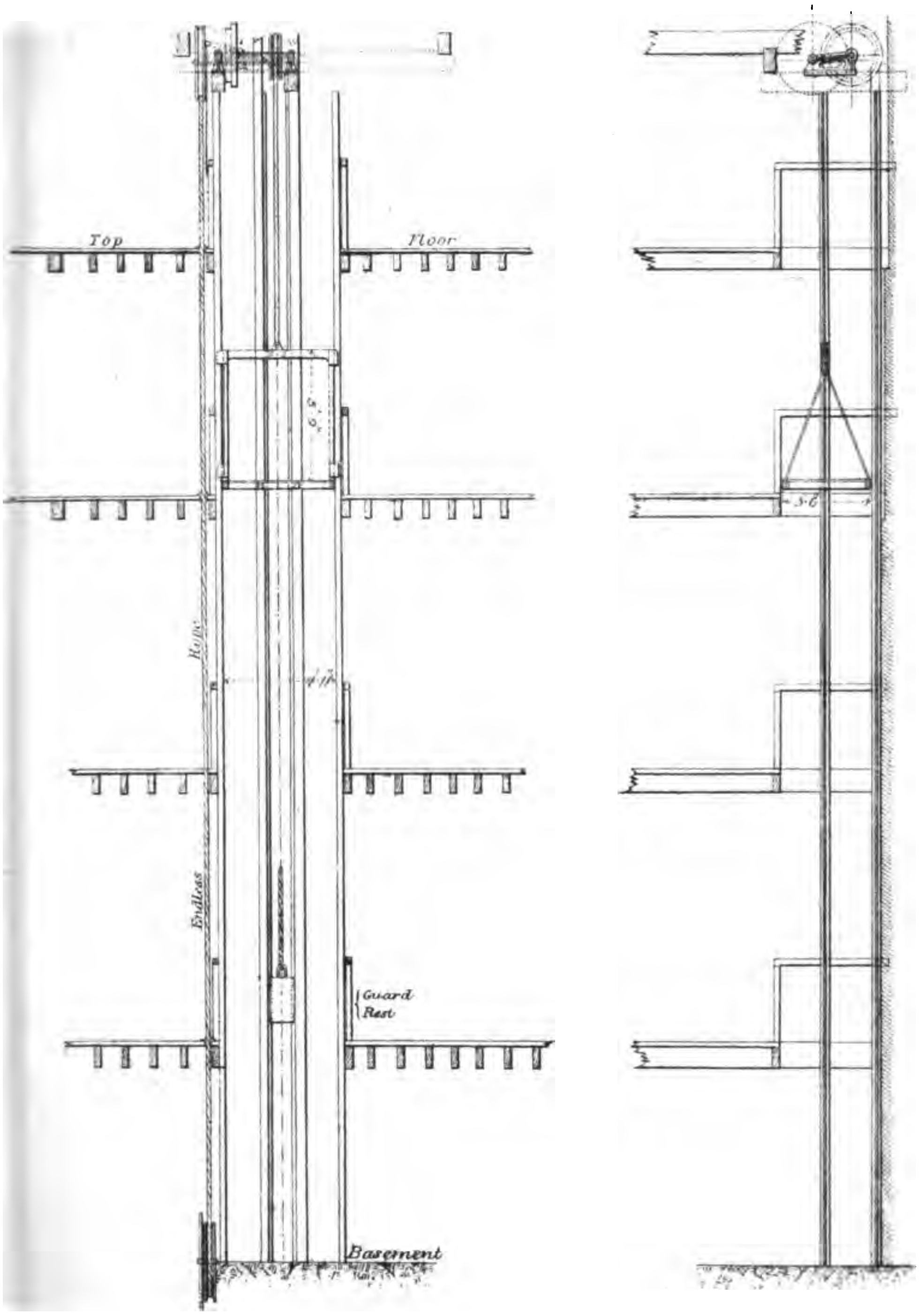
F. COLYER, M.I.C.E.

HAND POWER WAREHOUSE LIFT



F. COLYER, M.I.C.E.

HAND POWER WAREHOUSE OR PASSENGER LIFT

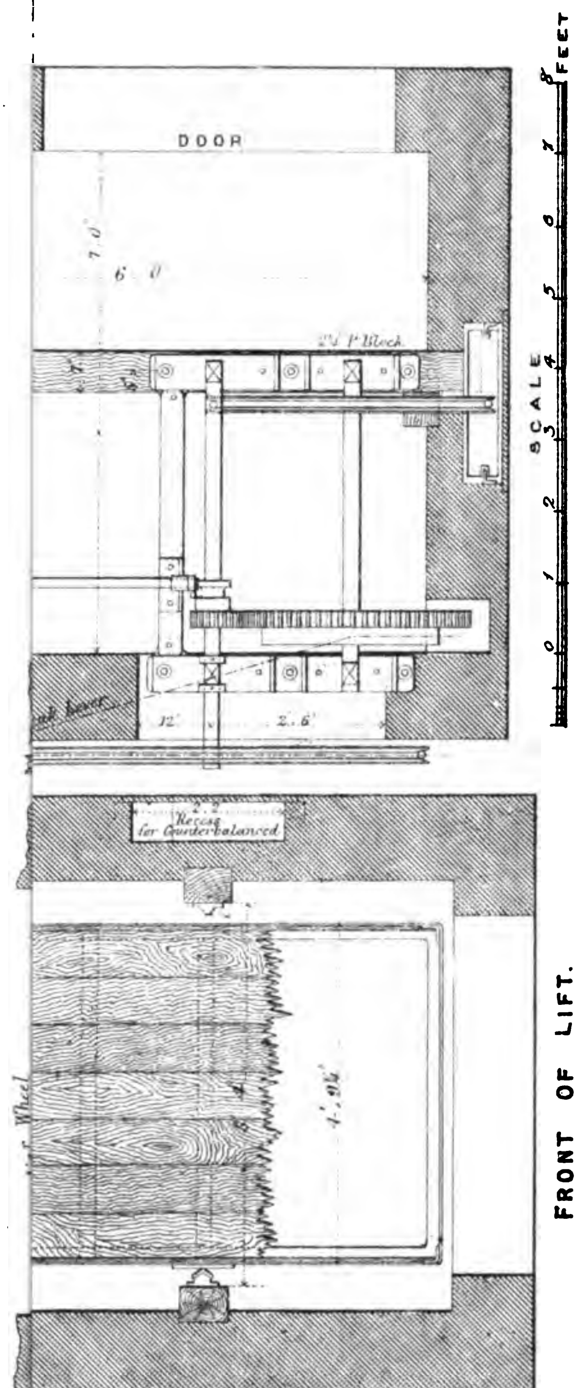


F. COLYER, M.I.C.E.

HYDRAULIC LIFT

DRAWING No. 79.

HAND POWER PASSENGER OR WAREHOUSE LIFT

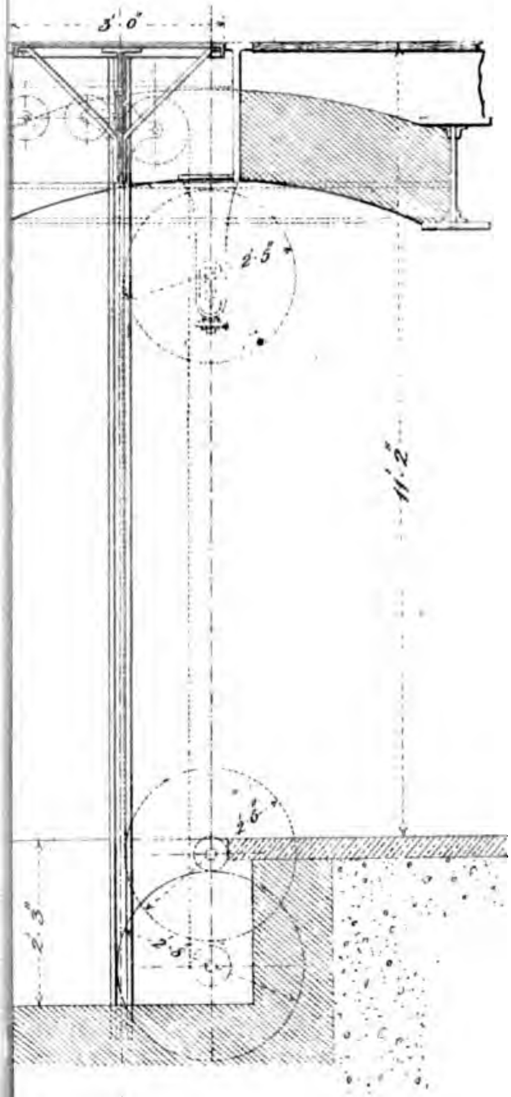


PLAN C.D.

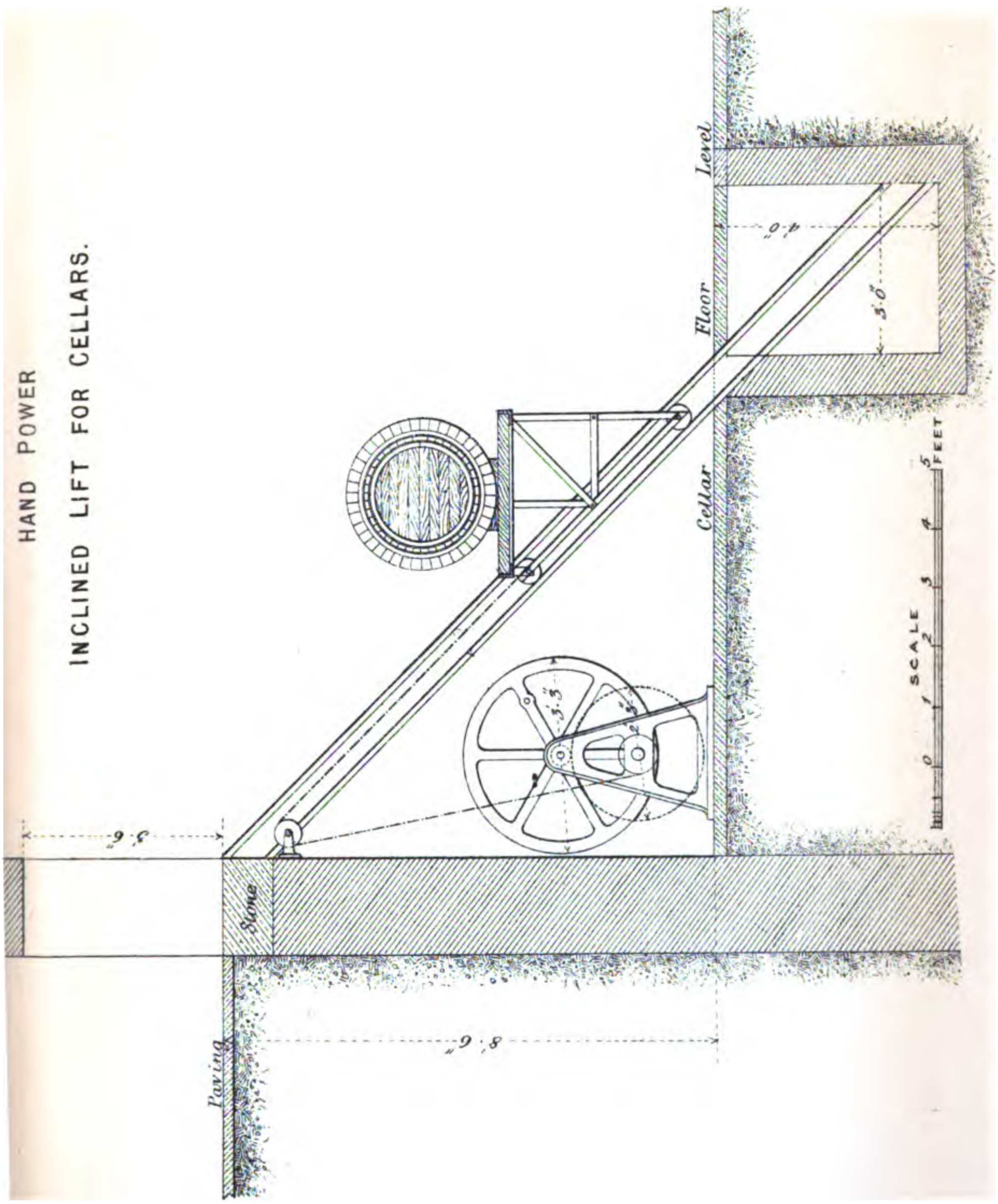
F. COLYER, M.I.C.E.

HYDRAULIC LIF

DRAWING Nº 80.



F. COLYER, M.I.C.E.

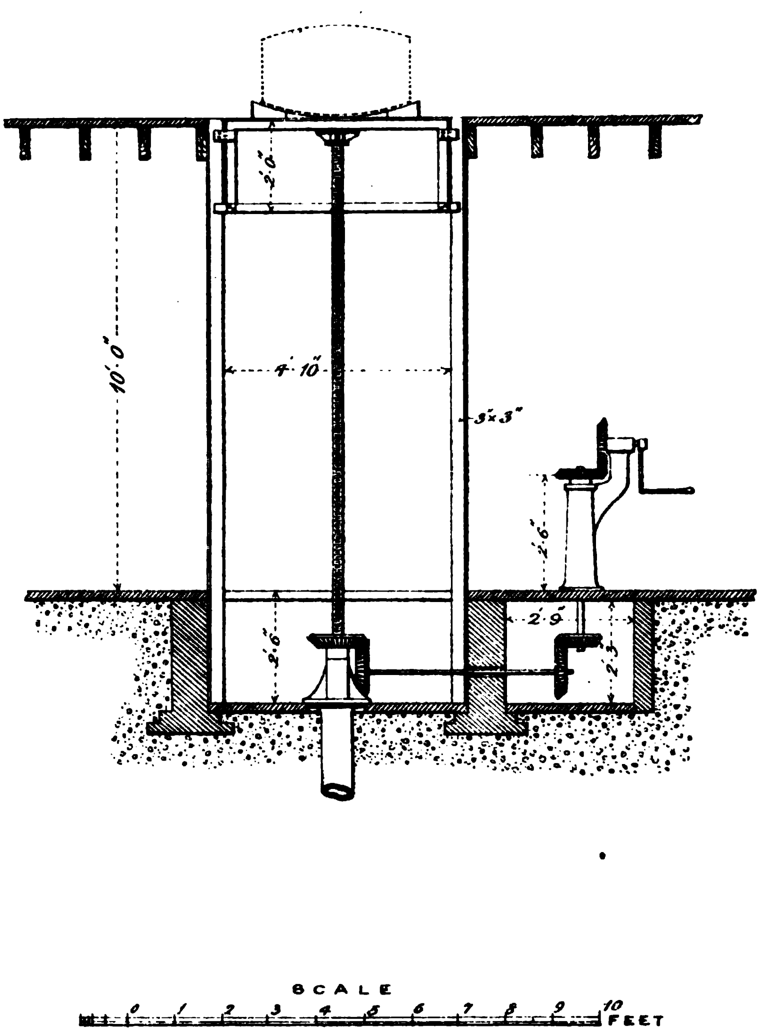


HAND POWER

INCLINED LIFT FOR CELLARS.

F. COLYER, M.I.C.E.

HAND POWER SCREW LIFT.



F. COLYER, M.I.C.E.

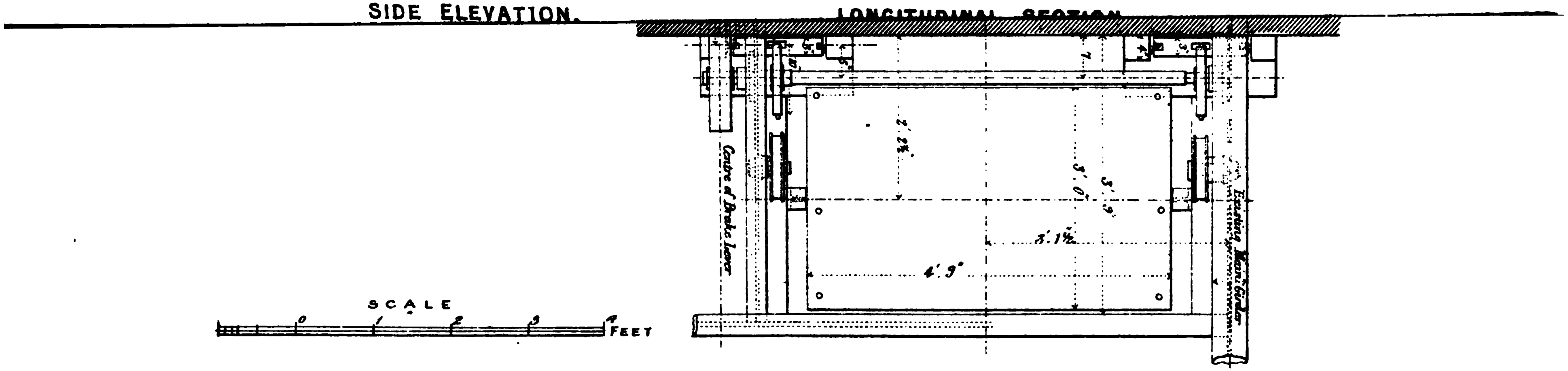
HYDRAULIC LIFTING AND PRESSING MACHINERY.

DRAWING No. 84

LOWERING MACHINE

SIDE ELEVATION.

LONGITUDINAL SECTION.



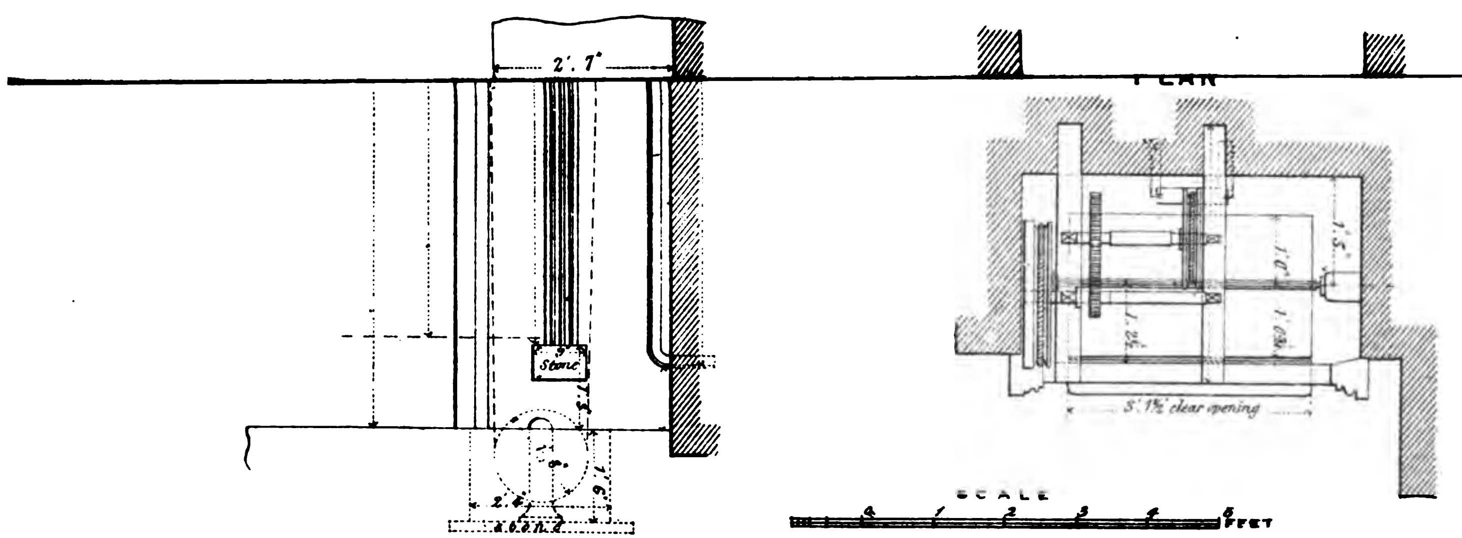
PLAN.

F. COLYER, M.I.C.E.

DRAWING No. 85.

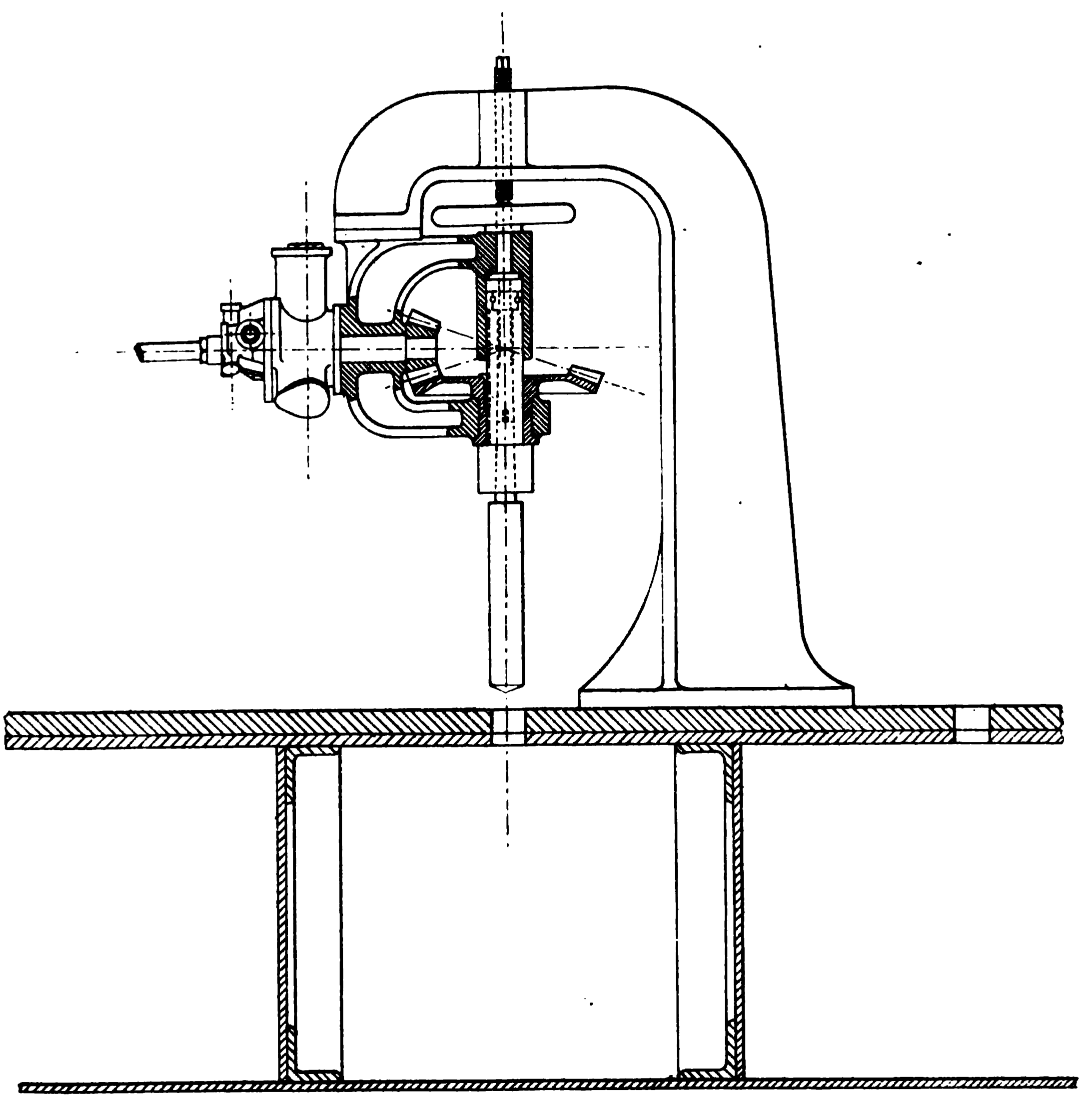
HOUSE LIFT

SIDE ELEVATION. **FRONT ELEVATION.**



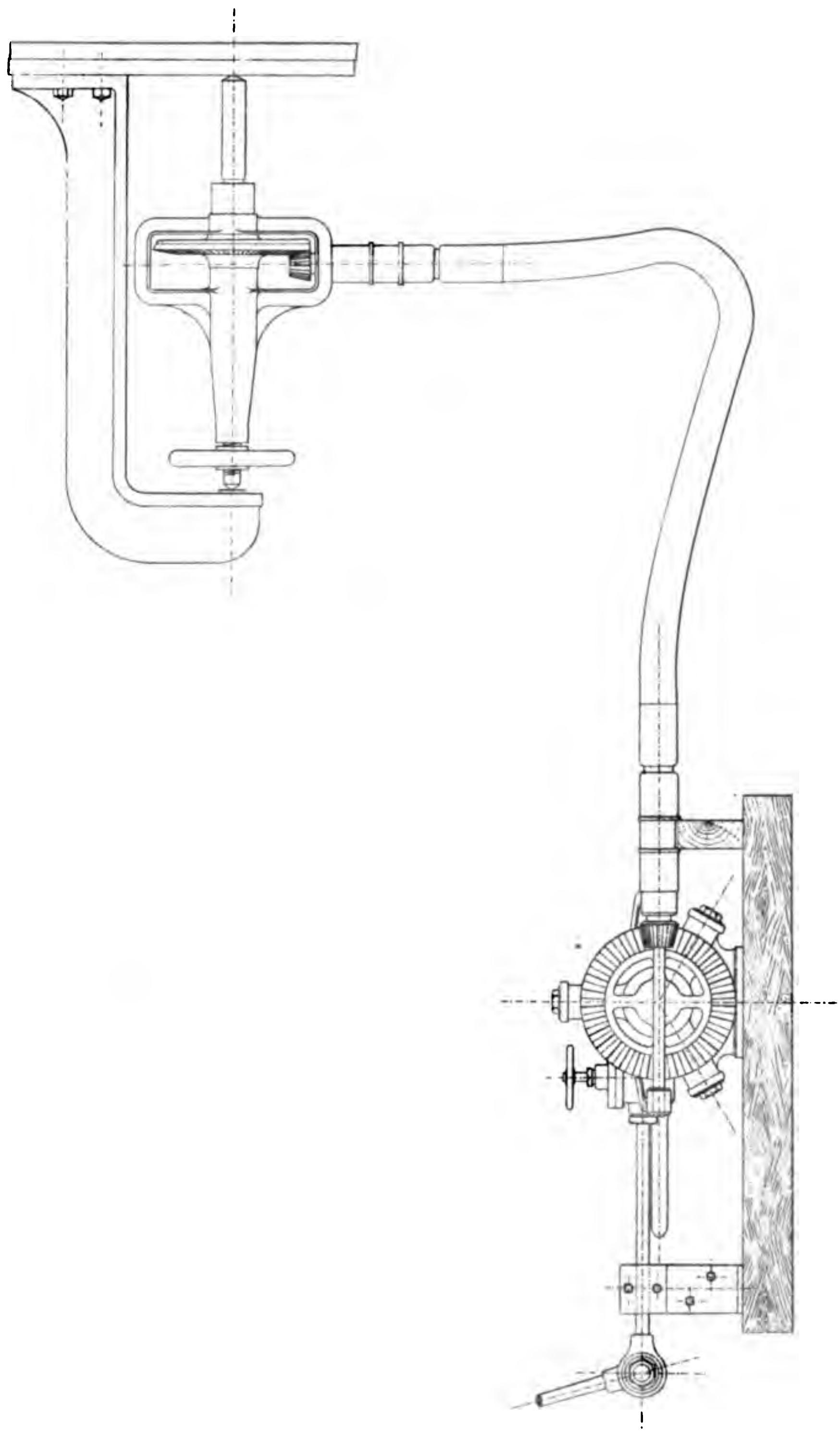
F. COLYER, M.I.C.E

HYDRAULIC DRILLING MACHINERY.
BERRIER FONTAINE'S SYSTEM.



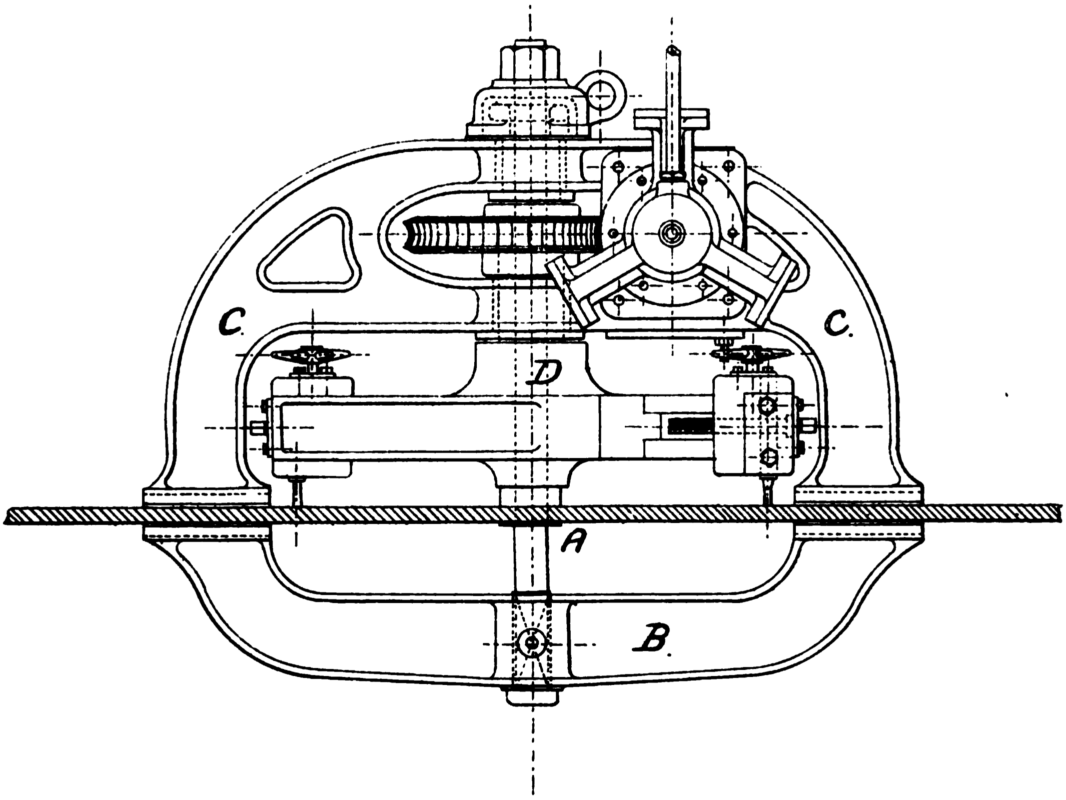
E. COLYER, M.I.C.E.

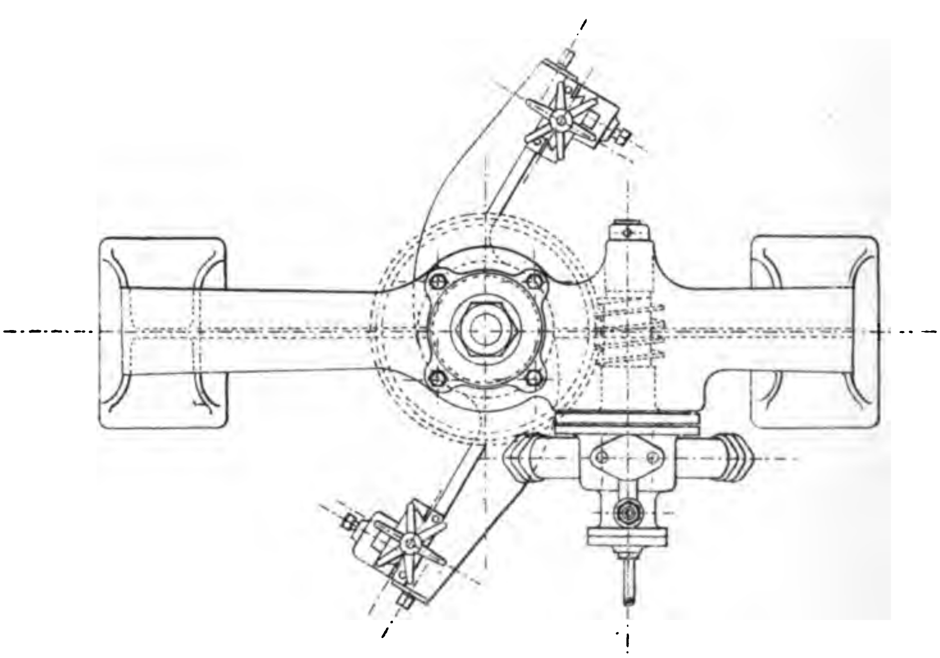
HYDRAULIC DRILLING MACHINERY.
BERRIER FONTAINE'S SYSTEM.



F. COLYER, M.I.C.E.

HYDRAULIC BORING MACHINERY.
BERRIER FONTAINE'S SYSTEM.





F. COLYER, M.I.C.E.

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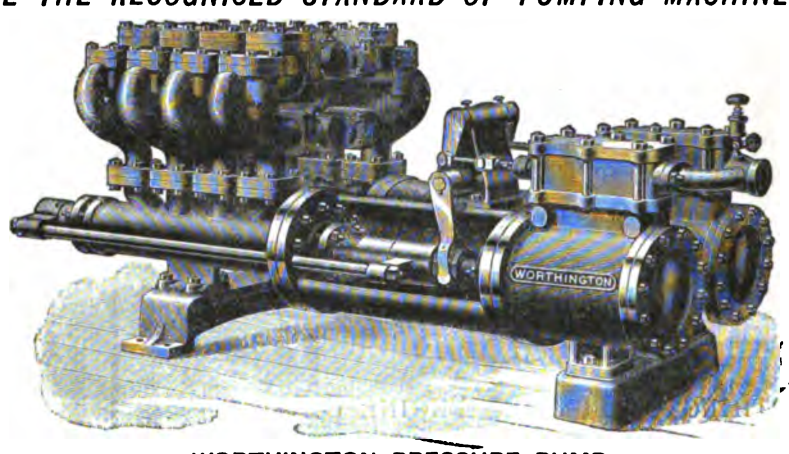
WORTHINGTON PUMPS

ARE THE RECOGNISED STANDARD OF PUMPING MACHINERY.



WORTHINGTON PRESSURE PUMP.

This pattern of pump is especially designed for driving Hydraulic Lifts and Cranes, Cotton and Hydraulic Presses, for Oil Pipe Lines, Mining purposes, and such service as requires the delivery of liquids under heavy pressures.

In the Worthington Pressure Pump the ordinary interior double-acting plunger is replaced by two plungers, or rams having external adjustable packings, readily renewed, which work into each end of a cylinder having a central partition. The plungers are connected together by yokes and exterior rods in such a manner as to cause them to move together as one plunger, so that while the one is drawing, the other is forcing the fluid, thus making the pump double-acting. The valve boxes are also modified for the purpose of subdividing them into separate small chambers, easily accessible and capable of resisting very heavy pressures. The general arrangement shown in the engraving is subject to numerous alterations, to adapt the pump to different requirements. The general characteristic of independent plungers with exterior packing is, however, in all cases preserved, as being not only more accessible in case of leakage, but also as allowing the use of different forms and material of packing. The severe pressure to which these pumps are often applied, not less in some cases than 8,000 lbs. to the square inch, demands the most thorough construction and the use of the very best material.

WORTHINGTON PUMPS FOR ALL SERVICES AND PRESSURES.

CATALOGUES AND ESTIMATES ON APPLICATION.